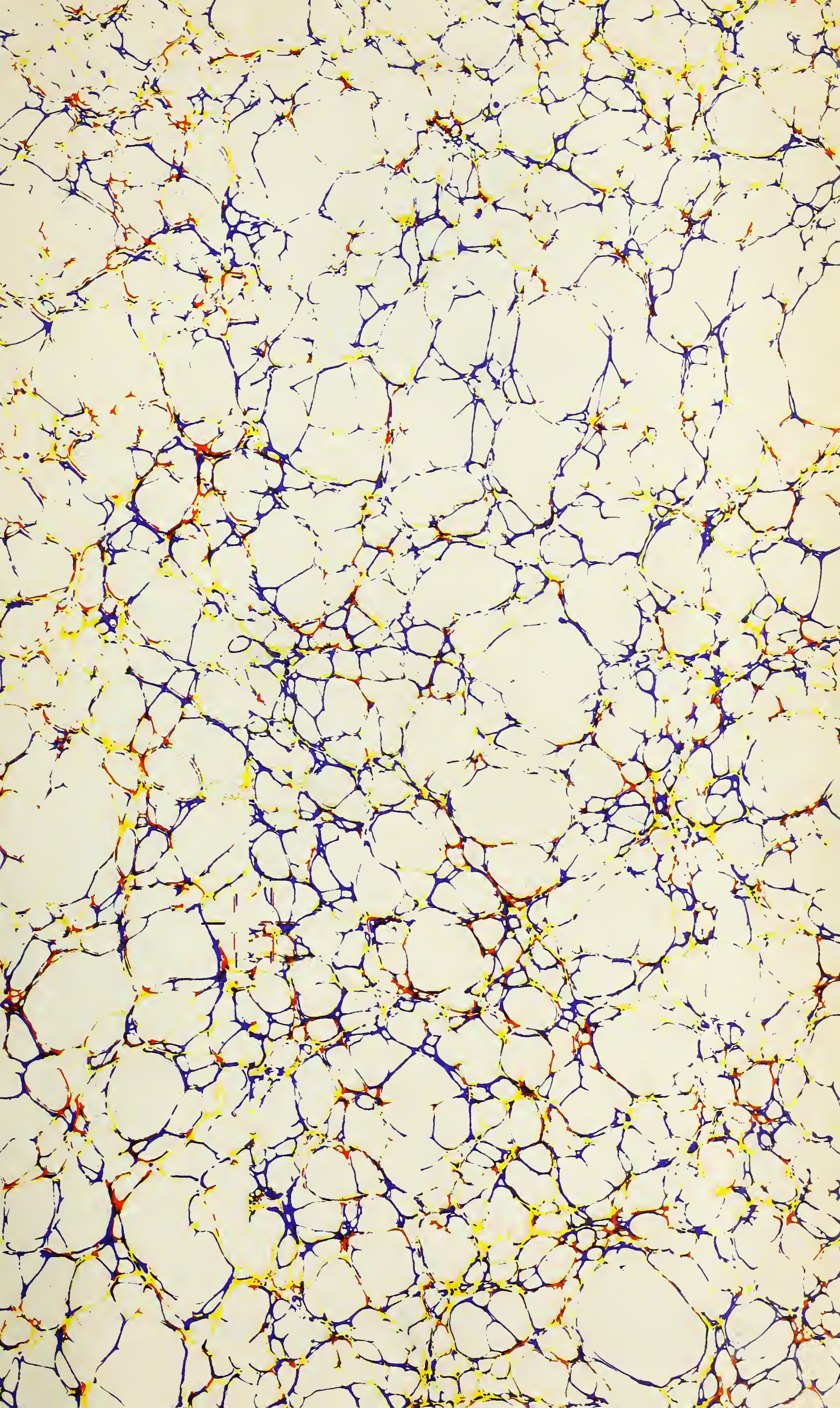


# SOIL DEFENSE OF ANGE AND FARM LANDS IN THE SOUTHWEST




MISCELLANEOUS PUBLICATION 338

UNITED STATES DEPARTMENT OF AGRICULTURE

*The Southwest, as considered in this publication, is a geographical region including all of Arizona and New Mexico. Some discussion of erosion conditions and corrective practices in use in Utah and western Colorado are also included. The whole area is a region of range lands and irrigated farming lands designated, for administrative purposes, Region 8 of the Soil Conservation Service.*

---

Washington, D. C. Issued June 1939

# Soil Defense of Range and Farm Lands in the Southwest

▽ ▽ ▽

By E. M. ROWALT

*Soil Conservation Service*

*In collaboration with subject-matter specialists of the Southwest*

## Contents

| | Page |
|---|---|
| Soil erosion in the Southwest | 1 |
| Changed vegetation and lost soil | 3 |
| Water supplies in jeopardy | 7 |
| Sources of silt and water | 11 |
| Lost land | 13 |
| Floods in northern Utah | 21 |
| Controls and cures | 23 |
| Range management: the key | 24 |
| Structural aids in erosion control | 30 |
| On the Navajo and Hopi Reservations | 38 |
| In the valleys of northern Utah | 43 |
| Checkrein on a river | 45 |
| On dry-farming lands in New Mexico | 47 |
| Extending controls and cures | 50 |

MISCELLANEOUS PUBLICATION 338

UNITED STATES GOVERNMENT PRINTING OFFICE

WASHINGTON : 1939

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - - - - - Price 10 cents

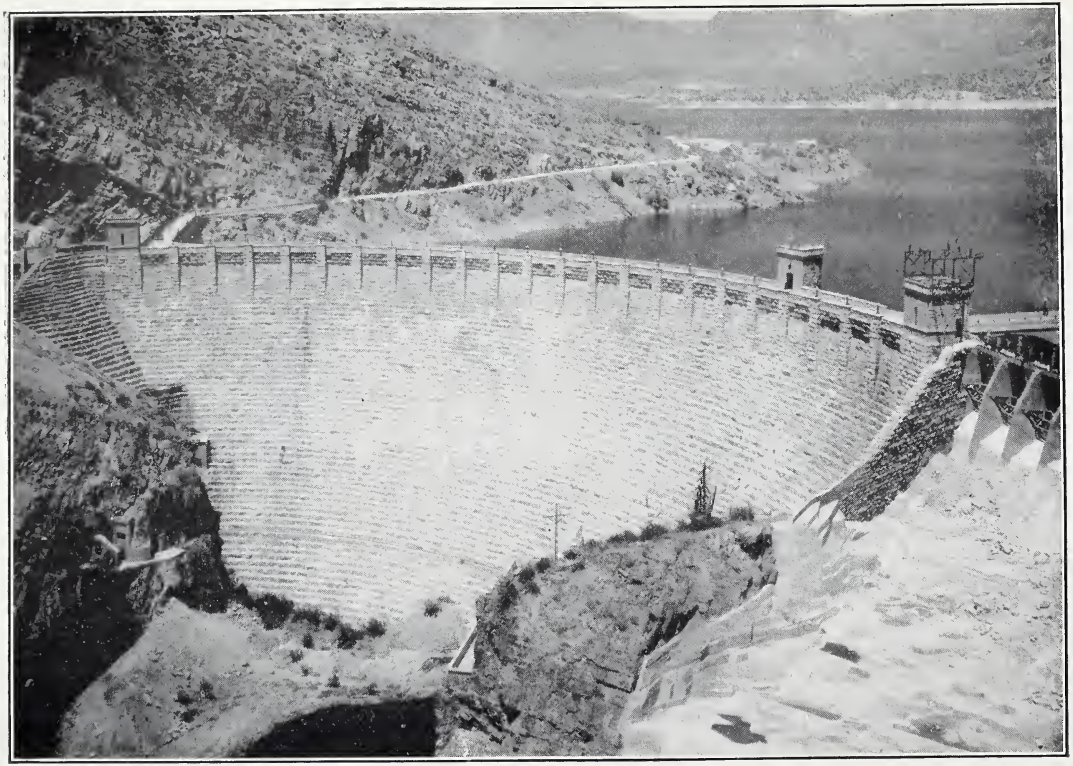


Figure 1.—*The public has advanced many millions of dollars to build dams. Rivers carry great loads of silt into the reservoirs behind these dams.*

# Soil Erosion in the Southwest

It is becoming increasingly apparent, as evidence gathers, that the range-livestock industry and irrigation farming, two of the three principal industries of the Southwest, are threatened by soil erosion. The thin film of surface soil that nourishes the vegetation that stock convert into beef, mutton, and wool and absorbs the water that keeps streams alive and steadily flowing, is washing from range lands at a rate for which there are few known precedents anywhere in the world.

Erosion is not a new process; it is old; older than the hills. It began with the first rains and the first winds and has been going on ever since there has been a body of land on this planet. For countless ages wind and running water have been wearing away the land. Indeed, geologic erosion plays a part in building soil, in making the land habitable to man. But where there is a cover of vegetation the process is restrained, held nicely in control. When the vegetation is cleared from the land by cultivation, overgrazing, fire, or destructive logging or is weakened by drought, erosion speeds up destructively, and soil is removed by running water and wind at rates many times faster than before.

Then we have soil erosion, or accelerated erosion, which is distinguished from geologic erosion in that it is man-induced. Man causes it by upsetting natural balances when using the land. In the Southwest, stocking of the range beyond its grazing capacity continuously is largely, but not wholly, responsible for accelerated erosion. There are other causes besides overstocking: The old wagon-freight trails that rutted the sod in the valleys, careless handling of water from roads, disturbance of natural drainage by railroad embankments, promiscuous cutting of trees for fuel, for railroad ties, and to sustain mining operations.

The consequences of accelerated erosion in the Southwest are far reaching. Damage is not restricted to the loss of forage and soil from the range lands. Soil erosion and rapid surface run-off and floods usually are associated; often they are companion phenomena. In recent years floods of increased violence frequently have inundated villages, towns, and cities. Farm lands and irrigation works along the principal rivers, where the bulk of the population lives and labors, have been damaged or ruined by overwash of sand and gravel, by waterlogging, and by cutting of new channels. Whole villages have been deprived of

the means of self support. Their people have migrated, or they have gone on relief. Trade has suffered. And the rivers carry heavy silt loads—the soil from the range lands—which are filling reservoirs, endangering the supply of water for the irrigated farming areas below the great dams, for municipalities, and for turning the turbines that generate power for industry.

More than half of the land in the Southwest is publicly owned. Only 40 percent of the land is owned privately. Most of the timbered land is in national forests, which comprise 15 percent of the region. Nine percent is in Indian reservations, 25 percent is in the public domain, and 3 percent is in national parks or is otherwise under the stewardship of the Federal Government. Eight percent is owned by the States.

Much of the most severe erosion in the Southwest may be observed on land under the stewardship of the Federal Government. On the whole, the lands in the national forests are in fair to good condition, for they have been administered many years with watershed protection as a major consideration. However, where accelerated erosion is damaging land in the national forests, such damage is usually of a serious nature. The forests lie on the higher, steeper slopes, receive more rain, and when the cover of vegetation is impaired the soil erodes rapidly. Except lands in the national parks, which are not grazed by domestic livestock, lands in public ownership outside the national forests have deteriorated greatly. Until grazing districts were established under authority of the Taylor Grazing Act, public-domain lands were subjected to unregulated grazing, and since they lie in the more arid portions of the Southwest, they break down more quickly following overuse and drought and recover more slowly. On many of the watersheds, lands in the public domain are the heaviest contributors of silt to the rivers.

The responsibility for range depletion and accelerated erosion on federally owned land may be laid on the Federal doorstep. The past public land use policy, drawn to fit the country as a whole, has failed to meet the special requirements of a region having a semiarid climate. This is unfortunate, for it has endangered both private and public property in the Southwest. The public stake in the Southwest is unusually large. Through various governmental agencies, the public has advanced funds for building dams costing many millions of dollars (fig. 1). It has advanced funds for the support of irrigation and drainage districts, and for many other public works. But until recently, little was done, aside from establishing the national forests, to protect these public and private improvements downstream from damage caused by overuse of lands upstream.

In the past several years the Government has initiated a number of programs to conserve and protect resources such as the soil. The Congress and many of the State legislatures have passed acts that provide mechanisms through which the Government and operators of ranches and farms may attack the problem of soil

conservation cooperatively. Among these are the Taylor Grazing Act, which established the Division of Grazing in the Department of the Interior; the several conservation acts which authorized the Department of Agriculture to undertake soil conservation and erosion-control work; and the State soil conservation districts laws.

One of the acts passed by the Congress established the Soil Conservation Service. This Service was charged with effecting erosion-control practices on a watershed basis, in recognition of the need for meeting the problem in its entirety rather than on a piecemeal basis. Watersheds were selected on which problems caused by erosion were especially critical, where damage near the headwaters upstream was causing serious consequences downstream. Among those chosen in the Southwest were the middle and upper Rio Grande Valley, the upper Gila Valley, the watersheds of the San Juan and Little Colorado Rivers, and some other smaller watersheds in Utah and Colorado.

In setting up watershed projects containing over 59,000,000 acres of land, the Soil Conservation Service took the first step beyond a demonstration program in the Southwest. This action recognized the high degree of public responsibility, particularly Federal responsibility, for erosion control in this region, and the close relationship between range use and erosion on upper watersheds and damage to reservoirs, rivers, and irrigated farm lands downstream. It is a program in which public agencies and individuals each assume their share of responsibility for erosion-control work on a large scale on public and private lands.

An over-all watershed picture for these areas is provided by watershed surveys covering all phases of land use and condition and human need. This picture is the basis for the selection of critical erosion- and silt-producing areas on the watersheds, areas where erosion control is badly needed and which, in the light of the entire watershed picture, must come first under erosion-control treatment. In this way, the lands throughout these multimillion-acre districts are treated as parts of a unified whole instead of as separate units without relation one to another. Farm and ranch, range land and irrigated land, fall together into a living mosaic that forms the basis for erosion-control operations in the Southwest.

## Changed Vegetation and Lost Soil

In the Southwest, where the climate is arid and semiarid, nature's balance is unusually delicate. Tip the balance only lightly in one direction and major transformations occur in plant and soil relationships which lead quickly to plant and soil deterioration.

In their studies on the upper Rio Grande watershed, C. K. Cooperrider and B. A. Hendricks, range examiners for the Southwestern Forest and Range Experiment Station, observed the deterioration in vegetation and the pick-up in erosion rates that followed. Disappearance of the original vegetation and erosion of the surface soil, they reported, are interactive factors, one adversely affects the other. As the vegetation on a watershed deteriorates, they observed, the topsoil gradually washes away, and in some places even the subsoils disappear. With the loss of the topsoil, the range plants, especially the grasses, are deprived of their main sources of subsistence, including both available water from summer rains, on which the grasses largely depend, and nutrient elements, particularly nitrogen. With the absorptive topsoil gone, the rain water, instead of soaking into the ground as it formerly did, quickly collects as damaging accelerated run-off. Finally the grasses die as the result of the baring of their roots or of being deprived of sustenance; or they are actually washed out and carried away with the soil.

In the earlier stages of range deterioration, the rate of soil deterioration is relatively not so great as that of the vegetation, according to Cooperrider and Hendricks. They explain this, pointing out that much of the topsoil material still remains and absorbs a part of the precipitation, thus checking accelerated run-off to some degree; and that, so long as topsoil remains, more annual herbs appear in the cover as the perennials disappear. The annuals temporarily afford some protection to the ground. However, after the vegetation declines about a third, soil erosion reaches critical rates and becomes destructive. After this stage is reached, the rate of accelerated soil erosion becomes relatively greater than that of the deterioration of the vegetation.

In the Southwest the change in vegetation following overuse is seldom from one sod-forming grass to another, as it usually is on the plains to the east. This difference is most striking to a newcomer. J. L. Lantow, in charge of range management for Soil Conservation Service projects in the Southwest, recalls how vegetal deterioration differs in New Mexico from that in Kansas. Remembering his boyhood there, he wrote:

As a boy I helped herd cattle on the unfenced Kansas prairies, and I cut hay on areas that had been little used for grazing, other than by game animals. My father told me about the country when he came there. The composition and species of grasses changed from place to place, he said, as grazing and climatic factors varied, but where lightly grazed, the grasses were largely the so-called big bluestem and little bluestem and, here and there, buffalo grass. As time went on the prairie that was fenced and stocked heavily lost all of the big bluestem quickly, and finally the little bluestem, being replaced by buffalo grass entirely. The buffalo grass first took full charge at the head of the lane where the livestock converged. Here the bunchgrasses gave way first. These happenings I saw, and I heard my father discuss with his neighbors the reasons

why the pastures were going back, why they should not be burned, and why overstocking was detrimental. Nevertheless, overstocking and burning went on. When I grew up, I came to the Southwest. But here, when the bunch-grasses were killed out by trampling or overstocking, I did not see sod grasses come to the aid and support of the soil, especially in areas having a potential of 10 livestock units or less to the section. I have seen some of the grama grasses (fig. 2), as well as some others when excessively used, replaced by curly mesquite where soil and rainfall permitted, and by bluegrass on lands of higher elevation. And where extra water ran over tight soil, I have seen burrograss often make a sod in light rainfall sections. But the more prevalent replacements are unpalatable nonsod-forming vegetation, such as three-awn grass, snakeweed, and burrobrush.

FIGURE 2.—*Blue grama grass, one of the best of the forage grasses, covers great areas of the Southwest.*

Some 35 years ago Salt Lake City, in northern Utah, purchased two water-sheds for city water supply. At that time, these watersheds were in the paths of sheep trails, and vegetation consequently was badly depleted. After the city acquired the land, grazing was deferred for an extended period, and the vegetation has recovered. The density of the vegetation now present is thought to approximate that of the original cover. In 1937, when these watersheds were inspected, the examiners found and identified a great variety of grasses, clovers, and browse plants.

The streams in the valleys were clear, and the party was told that flow was fairly uniform throughout the year. At the head of a reservoir in one of the valleys there was scarcely any silt.

Inspection of the cover in Immigration Canyon nearby, in which grazing then was unrestricted, revealed only remnants of the original grasses, and these remnants were hard to find and identify. There was very little sagebrush in the canyon, but many weeds, chiefly snakeweed. There was a little oak, some stunted snowberry, and squawbush. The stream bed in the canyon was dry at the time, early November.

Throughout much of Arizona and New Mexico, sacaton once covered the low alluvial flats and bottom lands subject to flooding. According to accounts of Indian wars, the horses of the United States cavalry were fed hay cut from these bottoms. Although these natural hay meadows made up only a small proportion of the grasslands, they were, particularly in the semidesert areas, a highly important source of feed in the early days of ranching. Few of these meadows remain. Where sacaton flourished, in the lowest parts of the valleys, the land is now generally cut and crosscut by gullies and arroyos. There is no longer enough moisture in the gullied valleys to support sacaton, for water, instead of gently flooding the alluvial flats and deeply wetting the soil, rushes into deep channel trenches and is lost.

## The San Simon Valley

Living men tell of the transformation that has occurred in 40 years in the Gila Valley in Arizona. Fierce, bloody attacks by Apaches discouraged the settlement of some parts of the valley until the late 1880's. Consequently the history of the early days of ranching in the Gila country is fresh. The late Will C. Barnes knew the San Simon Valley, a side drainage to the Gila, as it was 58 years ago. He revisited the valley 15 years later, and again in 1934. The transformation that had occurred moved him to write for American Forests a description of the valley as he first saw it and as it is today. As it was in 1880, according to Barnes:

The meadows were covered with soft lush grasses. On the more open areas those fine stock grasses, black, blue, and hairy gramas, grew luxuriantly. Along the wash were tracts of alkali land on which sacaton touched my stirrups. A little farther back large areas were covered with another useful forage plant, hilaria, one of the first to "green up" in the spring. Running back to the foothills on each side, the grama grasses covered the whole range with their rich growth, while several sages grew in dense bodies, furnishing splendid forage in winter when the range was covered with snow, or in dry seasons when grass was short. The old-timer with me summed it all up when he said: "What more do you want? Here's grass of every kind, some for good seasons an' some for dry ones. There's plenty of browse for winter an' trees full of mesquite beans

for the hungry cows every fall. There's water, but not too much of it, which is a good thing for any range."

Of the stream itself:

> There were then practically no banks to the stream. It simply flowed softly and quietly on top of the ground, except at its lower end where it entered the Gila. As I remember it, the banks of the San Simon at the junction were not more than three feet high and the wash itself measured not over 20 feet from bank to bank. Great cottonwood trees—the pioneer's best friend—and willow thickets lined its banks.

Soon after Barnes left the valley, Apaches from the San Carlos Reservation raided the Gila country, burning ranch houses and murdering settlers. The Gila River was the Indians' main highway down to old Mexico. "I did not crave a ranch in their vicinity," he wrote, "I sought further for a new location."

Within the next 15 years southwest Arizona was discovered by west Texas ranchers crowded from their own State through the leasing of State-owned lands to other stockmen. Barnes estimated that 50,000 head of cattle grazed in the San Simon at the time of his second visit, in 1895. A few years later the big outfits shipped their herds to eastern markets and went out of business. The grass was gone.

Following his last visit, in the fall of 1934, Barnes wrote (fig. 3):

> Many of the old valuable grasses and forage plants were gone. The meadows were replaced by drifting sand. Of running water, except during the summer rains when floods occurred, there was almost none. The ranges on both sides of the deep wash were criss-crossed by deep trails first worn by the feet of restless herds and then dug deep in the loose soil by the storm waters. On both sides of the main wash, side washes headed into it from the mountain slopes. Where the San Simon wash was originally not more than 20 feet wide, at the Gila, it was now fully 100 feet wide, and 30 feet deep. In some places above the junction the San Simon had widened out to 200 feet, and the cut extended back 60 miles.

# Water Supplies in Jeopardy

The Southwest is a region of forested and brush covered mountains, semiarid grassed tablelands and valleys, and arid lowlands. Somewhat less than 3 percent of the land is cultivated, and about two-thirds of all cultivated land is irrigated. The rest, about 97 percent, is range and timberland much of which is suitable for livestock grazing but not for farming. Lacking sufficient rainfall to grow crops without supplemental water, except on a small acreage of the higher tablelands, the Southwest can develop little agriculturally except along her streams. The life of the region literally flows in the rivers and streams that



126376°—39——2

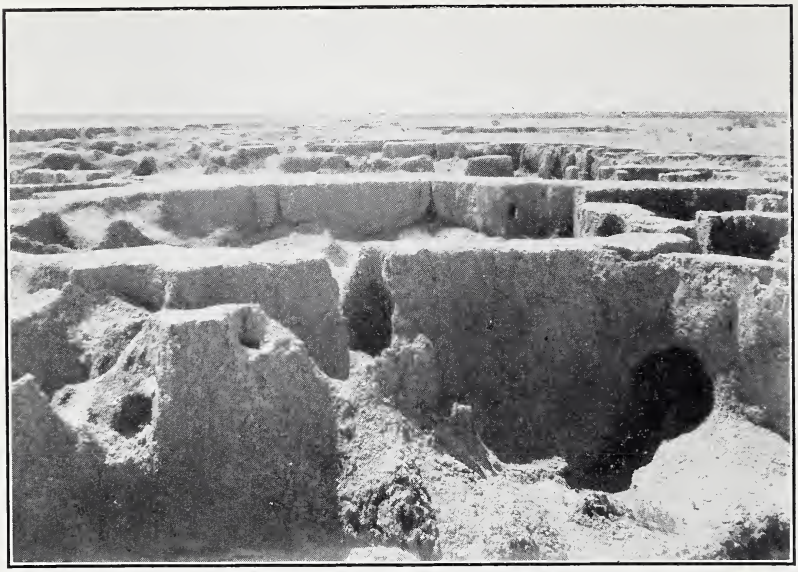


FIGURE 3.—*Not many years ago sacaton grasses growing on this flat in the San Simon Valley would have concealed a cow.*

course through the valleys. Villages and towns are strung along the streams and rivers like beads on a string.

To the farmers of the Southwest, her streams always have been her rain clouds. In the valley of the Gila there are ruins of irrigation works many centuries old, built probably by the forefathers of the Pima Indians. Some of the larger works are admirably planned and exact in grade, and would do credit to modern-day engineering. Three hundred years ago the Spaniards, moving up the valley of the Rio Grande, settled on the banks of that river, copied the practices of the Pueblo Indians, and grew corn, beans, and chili in small irrigated fields. The Mormons, coming to Utah centuries afterwards from the East, diverted water from small mountain streams and transformed semiarid valleys into gardens and orchards. Finally, twentieth century engineers built great structures of concrete and steel across the rivers—Elephant Butte, Coolidge, Roosevelt, and Boulder Dams—and turned lowland deserts into great groves, truck gardens, alfalfa meadows, and cottonfields (fig. 4).

The future of these irrigation projects, and the future of the people living on them, depends in a large degree on the manner in which the watersheds that feed them are managed. If, in the future, management is such as to reestablish a protecting cover of vegetation over the vast feeder watersheds, southwestern irrigated farming will be benefited. On the other hand, if management of the forests

and grasslands is such that vegetation does not recover in vigor and density, their future will be menaced by silt and flood.

Reservoirs are filling with silt. Not immediately, to be sure, but eventually the storage space behind the dams will be lost. Elephant Butte Reservoir on the Rio Grande, second in size in the Southwest only to the Boulder Dam development, was estimated at the time it was built, in 1914, to have a useful storage life of well over 200 years. In 1935, a party studying sedimentation rates found that the reservoir had lost 365,186 acre-feet of storage space, or 13.8 percent of its original capacity. If silting continues at this rate (fig. 5), the capacity of the reservoir will be reduced to less than normal annual draft requirements in about 84 years. Deposits of silt 15 to 30 feet deep have accumulated on the floor of the reservoir basin in 20 years.

The San Carlos Reservoir collected 36,896 acre-feet of silt, displacing 3 percent of its original capacity in a little more than 6 years—a period of low rainfall and little run-off. The watershed of the Gila River, the feeder stream to the San Carlos Reservoir, lies in a semiarid region which commonly experiences droughts of 2 or 3 years' duration. In order to assure a constant and adequate supply of water to the irrigation projects below the dam, the reservoir therefore should store enough water for about 3 years' requirements. Silting at

FIGURE 4.—*Twentieth century engineers built great structures of concrete and steel across the rivers, and lowland deserts were turned into groves, truck gardens, alfalfa meadows, and cottonfields. Date palms on irrigated land near Phoenix, Ariz.*

present rates will reduce the reservoir to this capacity in about 80 years. Upstream there is an almost unlimited quantity of silt available for transportation into the reservoir.

Roosevelt Reservoir, which supplies water to the highly productive lands around Phoenix, Ariz., lost 101,000 acre-feet, or 6.17 percent of its original capacity of 1,637,300 acre-feet, in the period between 1910 and 1925. This represents an average annual rate of accumulation of 6,733 acre-feet a year, or 79 cubic feet of soil each year from each acre of land in that part of the Salt River watershed above the dam.

Smaller reservoirs approach the end of their effective life more quickly. McMillan Reservoir, on the Pecos River, which supplies water for the Carlsbad project in New Mexico, lost 55.5 percent of its capacity of 90,000 acre-feet in 38 years, filling at the rate of 1.34 percent each year. Zuni Reservoir, on the Zuni River, filled with silt at a more rapid rate than any other major reservoir in the Southwest. This reservoir is now useless. It lost 76 percent of its original capacity of 14,800 acre-feet in 21½ years. Several attempts have been made to flush out the sediment, but none has been successful. In one attempt 5 percent of the silt was removed.

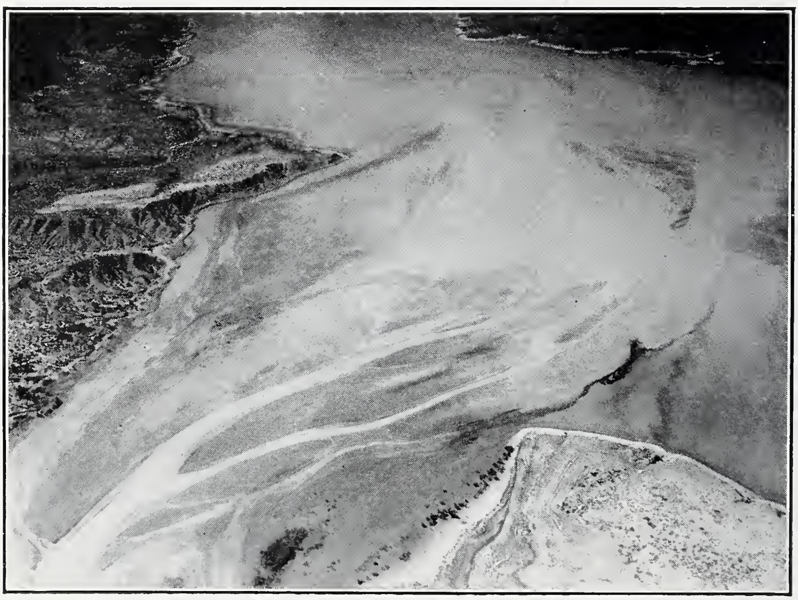


FIGURE 5.—*The silt-laden Rio Grande as it enters Elephant Butte Reservoir. If silting continues at present rates, the capacity of this reservoir will be reduced to less than annual draft requirements in about 84 years.*

FIGURE 6.—*Most of the water that finds its way to irrigated fields comes originally from the forests.*

There are few sites suitable for dams and reservoirs. In the Southwest the best sites have been developed. Once these reservoirs are filled with silt, new storage space may be provided, if at all, only at much greater expense. Staggering financial losses will of course be suffered when the dams come to the end of their period of usefulness. But such losses would be trivial compared with the social and economic distress which would follow if new storage space could not be provided at reasonable cost.

# Sources of Silt and Water

Most of the water that finds its way to irrigated fields comes originally from the forests (fig. 6). Forested and brush-covered lands, lying high on the mountain slopes, receive 20 to 30 inches or more of precipitation each year, much of it in the form of snow. The snow piles deep in the forests, and in the spring and early summer it melts. Much of the water flows to the mountain streams, causing the rivers to rise in prolonged spring flood. Part of it seeps into the soil, where it nourishes the vegetation or joins the ground-water flow, some of it eventually emerging as springs and finding its way into streams. Rivers rising in forests maintain a fairly even flow during the summer season, for then they are largely spring-fed; and they carry little silt. The San Francisco River in

southern New Mexico and Arizona is such a stream. It drains 3,000 square miles of forested and brush-covered land and carries only a trace of silt. Without exception all of the perennially flowing streams of the Southwest rise in the forests.

The great bulk of the silt load accumulated by the rivers comes from the side drainages that course through depleted grasslands (fig. 7) or those parts of the national forests which have not yet recovered from overgrazing, fire, or unwise cutting of trees for lumber or fuel. Such drainages carry great quantities of silt and little water. Either they flow violently or hardly at all. Usually they are

Figure 7.—*Most of the silt comes from side drainages that course through depleted grasslands.*

practically dry during most of the year. During the summer rainy period they occasionally flow violently, form washes and arroyos, and carry great quantities of range soil, often causing destructive flash floods, which ruin the crops, lands, and irrigation works of farmers downstream. The Rio Puerco and Rio Salado, which empty into the Rio Grande; the San Simon and San Pedro, which flow into the Gila River; and the Little Colorado and San Juan Rivers, tributaries to the Colorado, are examples. Some of the washes on the Navajo and Hopi Indian Reservations, a 15,000,000-acre block of land, carry half soil and half water in summer flood, delivering heavy loads of silt to the San Juan and Little Colorado Rivers and eventually to Lake Mead above Boulder Dam. It has been estimated that the Rio Grande receives about 40 percent of its silt load and only about 4 or 5 percent of its water from the Rio Puerco. The Gila River, at Safford, which lies

below the mouth of the San Simon, has been known to carry 25 percent of silt by volume when that drainage was in summer flood.

The silt carried by the streams of the Southwest comes largely from the great beds of alluvium that lie wedged between the valley slopes, and from the river banks. For ages past this alluvium had washed down from the surrounding hills, spreading evenly in flood over the valley floors. This gradual valley filling, proceeding at the imperceptible pace of geological movement, laid down alluvium in some places to a depth of 50 to several hundred feet, while nature held it in place in its new location with grass. Now that the grass is thin, and in many places practically gone, run-off from the valley slopes is no longer effectively impeded. It gains speed, volume, and erosive power, and, in draining through the valley, cuts gullies through the thick beds of erodible soil. The gullies quickly grow into deep, vertical-walled arroyos. When it rains, their banks crumble and fall, and floodwaters carry the silt into the washes and the rivers.

## Lost Land

The loss of storage space in reservoirs is by no means the only damage caused by stream-borne sediment. Fields and irrigation works suffer in several ways from flash floods and silt deposition. Stream channels rise and shift, and water which normally would be confined between banks, floods over adjacent lands, leaving behind an overwash of silt and debris. Lands adjacent to the rising, shifting channels become bogged and useless for cultivation or habitation. In the semidesert areas interruption of natural drainage leads to concentration of salts in the surface soil, rendering the land unsuitable for farming. Drainage may become difficult or impossible. Most irrigation companies spend large sums cleaning sediment from the bottoms of their canals in the spring, and this annual spring cleaning accounts for the major portion of maintenance charges. The San Carlos irrigation and drainage district, for example, spends approximately $100,000 annually cleaning out canals and laterals silted up by waters from the San Pedro River. So much silt has been deposited over some irrigated areas that it has become necessary to build higher diversion canals in order to continue irrigating the land.

The destructive effect of channel sedimentation is more difficult to measure than that of reservoir silting, but in terms of damage to property and resources channel sedimentation may be more serious. Reservoirs sometimes may be duplicated, but lands once lost cannot be replaced. The lands damaged or ruined by excessive sedimentation are those lying along the perennial streams, the most desirable sites for homes and, with few exceptions in the Southwest, the only sites suitable for cultivation (fig. 8).

FIGURE 8.—*Lands damaged or ruined by abnormal sedimentation are those lying along the perennial streams, the most desirable sites for homes and farms.*

The middle Rio Grande Valley in central New Mexico is an example. The rural population of the valley, about 55,000 people, depends chiefly on subsistence agriculture for a livelihood. They press hard against these valley lands, about 500 to the square mile. Theirs is an ancient agriculture. Indian farmers have irrigated here for a thousand years, Spanish-Americans for 300 years, and Anglo-Americans for nearly a century. The irrigable lands all were developed long ago. The farms are small, little larger than good-sized garden patches, and they are handed down from generation to generation and often subdivided. Seldom is a farm put up for sale. Until recently few were mortgaged. Their agriculture is not commercial farming (fig. 9). They may sell or trade a little chili or a few head of cattle, but most of the products they coax from their precious soil are eaten at home.

Although the Spanish conquistadores brought cattle, sheep, and horses to the Rio Grande Valley nearly 400 years ago, grazing on the watershed did little damage to the river-bottom lands until comparatively recently. Indians remained masters of the grasslands, and for many years yearlong grazing was restricted to range readily accessible to irrigated farm lands. It was not until the first tide of westward settlement gathered strength after the Civil War, when the Indians were subdued and the cattle boom burst on the country with explosive suddenness, that livestock grazed the entire upper watershed of the Rio Grande. The commercial livestock industry reached its first peak in the 1890's. Greatly accelerated erosion, silting, and more rapid rising of the river bed probably date from the beginning of depletion of the grasslands, brushlands, and forests in this period.

In the last half century the land situation has grown distressing. Many of the irrigated fields have become waterlogged and useless or have been covered by sand and gravel, since the Rio Grande got out of hand. Only estimates of the extent of the development of irrigated lands in the valley before 1897 are available. The story seems to be this: In 1800 about 100,000 acres were developed for irrigation; by 1880 about 125,000 acres had been developed, but by 1934 the area that could be cultivated had shrunk to 40,000 acres. Two-thirds of the irrigated acreage, roughly, has been abandoned in the last 50 years. To eke out a living, many of the families migrated seasonally to the beet and potato fields of Colorado and to the smelters and labored by the day, but even this opportunity was largely closed to them by the depression. The relief load in the valley has been heavy since 1934.

Immediately above the head of Elephant Butte Reservoir, the rising of the river bed of the Rio Grande has been responsible for such severe flood damages and swamping of valley lands that the town of San Marcial, which had a population of over 1,000 prior to 1929, has been almost completely abandoned. Since 1914, when Elephant Butte Reservoir was built, the bed of the Rio Grande at a



126376°—39——3

point a short distance above the reservoir has risen an average of about 13 feet, according to surveys made in 1936. Two miles farther upstream, just above the San Marcial town site, a rise of about 7 feet occurred during the same period.

Largely because of this rise in the stream channel, the dikes built to protect the towns and irrigated lands adjacent to the Rio Grande have been repeatedly overtopped and broken by floodwaters, with disastrous results. Many of the irrigated fields west of the river at San Marcial became swamps after the 1929 flood. In the spring of 1937 the Rio Grande broke out of the floodway to which it had been confined by dikes and followed a new course directly across the remaining irrigated lands lying east of the river.

The Rio Puerco joins the Rio Grande some 50 miles above San Marcial, delivering sediment to the Rio Grande much faster than the river can move it. Consequently, as shown by a comparison of surveys made in 1927 and 1936, the Rio Grande channel has been built up at rates as high as 9 inches a year. As a result, floodwaters in the spring of 1937 overtopped and washed out the levee and a paved highway and converted hundreds of acres of pasture land into a sandy waste. Large parts of the former irrigated lands at the village of Contreras have become swamps because water can no longer be drained into the river, which is now flowing at a level above that of the fields.

Some of these damaged lands may be reclaimed. At present the largest single effort is the Rio Grande Conservancy District, which was set up in 1927 to protect cities, towns, and utilities against flood damage and to reclaim some 70,000 acres by construction of drainage canals, storage works, and floodways.

At best, the prospects for success of this program are dubious unless the whole of the watershed, from the forests down to the banks of the river and its tributaries, is hereafter conservatively managed, which it has not been for more than half a century. Testifying at a flood-control hearing at Santa Fe in April 1938, Stanley Phillippi, assistant chief engineer of the conservancy district, said: "The maintenance of the channel under present conditions of silting is gradually becoming an impossibility." The whole project, he pointed out, is endangered by the great loads of sediment that are washing into the river from overgrazed range lands.

The Rio Grande is a perennial stream flowing through an arid and semiarid region. It derives its water largely from rain, melting snow, and springs in the forested mountains in Colorado and northern New Mexico. When it leaves the upper reaches of its watershed its waters are clear. It receives little further contribution as it flows south through New Mexico, except from the Galisteo, the Chama, the Jemez, the Salado and the Puerco, which course through overused range lands. The discharge from these streams is small except during storms, when they shove huge quantities of sediment into the channel of the

Rio Grande. The Rio Puerco, as previously mentioned, contributes only about 4 or 5 percent of the water carried by the Rio Grande at the mouth of the Rio Puerco, yet it is estimated that it contributes about 40 percent of the silt load entering Elephant Butte Reservoir. When the Rio Grande is in flood it carries, below the Rio Puerco, 10 times as much silt as an equal volume of Missisisippi River floodwater.

The grazing capacity of that part of the Rio Grande watershed between Elephant Butte Reservoir and the Colorado line is estimated at 140,000 cattle units yearlong. (One cattle unit equals five sheep units.) The number

FIGURE 9.—*Little of the agriculture along the Rio Grande and its tributaries is commercial farming. Most of the products grown are eaten at home.*

of sheep and cattle now using the range is estimated to be equivalent to 250,000 cattle units yearlong, which is about 80 percent in excess of present grazing capacity. This figure is based on all lands, 13,000,000 acres—the public domain, privately owned land, State lands, national forests, and railroad lands. Since some parts of the range are conservatively managed, large areas therefore are stocked far beyond their grazing capacity. If this ancient agriculture along the Rio Grande is to be saved, some drastic adjustments in range use and management must be made over the greater part of the watershed.

Figure 10.—*Streams, whipping from bank to bank in flood, have cut away many thousands of acres of agricultural land.*

## The Bank-Cutting Gila

The gradient of the middle Rio Grande Valley is moderate. That of the upper Gila Valley in southern Arizona is much greater. This valley slopes about 15 feet in a mile, and the river flows with greater force. The damage to irrigated lands here is of another kind. The Gila River, whipping from side to side in flood, cuts into its banks, taking a bite here and a bite there. When the United States Land Office surveyed the Safford Valley (a segment of the Gila Valley) in 1875, the area in the river bed was reported as 980 acres. At that time, which was before the settlement and the development of irrigation farming in the valley, the Gila River was held within a well-defined channel by banks lined with willows and cottonwoods. The channel was 150 to 200 feet wide. Now the river bed, instead of occupying 980 acres, covers 10,860 acres. The channel has widened to about a quarter of a mile, destroying almost 10,000 acres of the approximately 40,000 irrigable acres originally in this part of the valley. The kind of land that the river destroys, produces, when irrigated, acre yields of as much as 2 bales of cotton, 2 to 5 tons of alfalfa, 30 bushels of wheat, 40 bushels of barley, and one hundred 100-pound sacks of potatoes. Such land is valued at $200 an acre. Farther up the valley, at Duncan, the river destroyed 1,450 acres, according to local estimates. Such losses (fig. 10) have occurred elsewhere along the Gila and other streams of the Southwest since overgrazing depleted the grass on the watersheds and the cottonwoods were cut for fuel, but there are no available records to indicate the extent of the damage.

In 1863 the Government, harassed by civil war and fearing the warlike Navajos, sent Kit Carson to round them up. They were herded into Fort Sumner. After the war, in 1868, they were returned to their old haunts, and livestock was given them. About 8,000 Navajos were settled in the mesa and canyon country east and south of the Colorado River on a comparatively small reservation. That was 70 years ago. In the whole reservation, which from time to time has been enlarged until now it is a body of land about the size of the State of West Virginia, there are about 48,000 Navajos and 3,000 Hopis.

At first the Indians hunted and farmed and raised a few livestock for home use. Stock were fairly well distributed. Each family owned a few head. Only a small portion of their domain was suited to agriculture, less than 1 percent. Agriculture could be practiced only in certain favored places, as in the Chin Lee Valley and on the alluvial fans below small drainage areas. Here they grew small patches of corn, beans, and squash by practicing flood irrigation.

Then the railroads opened up the Southwest, white traders came, and the Indians were encouraged to raise more livestock. There was a ready market for lambs and wool, and the Navajos quickly developed into commercial stockmen. Some Navajos now own as many as 4 or 5 thousand head. Others own only a few or none. The stock all graze on the common land.

The Navajos have used their land hard. In 1931, according to a count taken at the dipping vats, more than 1,370,000 sheep and goats grazed the reservation ranges (fig. 11). It is estimated that the Navajos also own about 50,000 horses

Figure 11.—*More than 1,370,000 sheep and goats grazed the Navajo Reservation ranges in 1931.*

and 25,000 cattle. The reservation was stocked far beyond the grazing capacity of the ranges, and this excessive stocking, together with poor range management and periodic drought, beat down the grass. Erosion by both wind and water is devastating the land at a rate rapid even for the Southwest. The reservation is one of the great silt-contributing areas to the Colorado River above Boulder Dam.

The Navajos are worried about their land. But like many white stockmen they believe that their troubles stem from a change in weather. Recently, however, some of the Indians have come to realize that overstocking of the range is largely responsible for the erosion damage and depletion of the grass cover, and they talk about it in their native tongue. Chee Dodge, a Navajo leader, speaking in 1936 to a group of 100 delegates who had gathered to elect district representatives, voiced this appeal:

Sixty-eight years ago we came back from Fort Sumner. At that time we were just a small band. We also owned a very small band of stock. But, up to this day, we are told we have increased to 50,000. Also, our stock increased tremendously with us.

At that time we had plenty of grass for our stock. We just kept increasing our stock, thinking nothing about the grass our stock eats, thinking nothing about the soil the grass grew from, thinking nothing about our Mother Earth.

Years back a person could almost see the grass sprouting right after the rains. After it rained you could walk on the soil and it would sound like you were walking in the snow—cracking under your soles. But now the ground is just like cement. The only thing a person hears cracking are his knee-joints from walking on the hard ground.

Now what do you hear after it rains? You hear nothing but roaring of water down these gullies. We are told, and if you just do a little thinking you will also realize, that these gullies are made from soil exhaustion.

We have killed the grass with our stock, running them all over the reservation. Every time we herd our sheep we have a small dust-storm following our herd. Maybe all these small dust-storms from our herd form together and make a big dust-storm east of us.

We have nobody to blame but ourselves. The Government did not help us kill the richness of our soil. Washington never did herd any sheep or cattle on our reservation.

Now all of us old-timers have enjoyed the fruits of the earth; but what do you think of the coming generation? What do you think of those babies some of you are holding now? Will they enjoy the same things that we have enjoyed?

My people, let me tell you right here, they could if we give our Mother Earth the proper treatment she needs now. She is slowly dying, and I have already told you the reasons why.

Let's get behind the Government and help treat our soil so grass of all kinds will grow for our stock.

We will have to learn how to regulate our stock. We will have to learn about range management.

Now, old-timers! Have pity on these youngsters, the coming Navajos who

will take our place. They have no place to go. This is their reservation. If we had two or three reservations, it would be different.

If we have increased in 68 years from a handful to 50,000 what will the population of the Navajos be 30 years from now?

So let's do something for our reservation so the coming generation can again enjoy what we have enjoyed. How? Simply by helping the Government in their reclamation of our only land.

# Floods in Northern Utah

The Wasatch Mountain Range strikes through northern Utah just east of Great Salt Lake. Between the mountains and the lake there is a narrow alluvial plain 3 or 4 miles wide, part of the basin of old Lake Bonneville, which covered the region some 20,000 years ago. Between Salt Lake City and Ogden this plain is intensively cultivated and densely populated. It is the richest rural section of the State.

From the west slope of the Wasatch Range small streams issue from short, steep canyons and cross the plain into Great Salt Lake. During heavy rains in the summer of 1923 mud and rock flows belched from four of the canyons, causing loss of life and damage to private and public property and ruining many acres of valuable farming land. Floods occurred again in 1930. Since none had occurred from 1847, when the Mormons settled the valley, until only a few years ago, people asked why. Had the climate changed? Governor Dern, in 1924, appointed a committee of scientists to look into the matter; and later the Intermountain Forest and Range Experiment Station published a more detailed report in the Department of Agriculture's Miscellaneous Publication 196.

The committee found no evidence that the climate had changed but plenty of evidence that the cover of vegetation had. Overgrazing had removed vegetation from much of the land at the heads of the canyons. In some parts of the upper reaches of the watersheds too steep for livestock to graze easily, the canyon bottoms and slopes were densely overgrown with trees, shrubs, and smaller vegetation. The soil here was deep and covered by several inches of a litter of leaves and other organic material and was very absorbent. In contrast, the soil where stock grazed was in poor condition to take up moisture quickly. It was hard and compact; much of the absorbent surface layer was gone, for the area had been used hard by sheep and cattle for many years. There was little vegetation and little topsoil left on about one-fourth of the upper zones of the watersheds, and here the floods originated.

During summer rains water quickly collected in gullies on these denuded areas and gained velocity and erosive power as it swept down the steep slopes. The channels of the little canyon streams, which had remained relatively stable for

many thousand years, were cut 30 or 40 feet deeper, so great was the force of the avalanche of water, mud, and rock. The floods moved boulders weighing hundreds of tons and great masses of sand, gravel, and soil that had lain undisturbed since the time of Lake Bonneville. According to the geologists in the investigating group, the violence of the floods exceeded that of any floods since the time of the great prehistoric lake. They had moved greater quantities of material and larger boulders and cut deeper into the canyon than any floods in recent geological history.

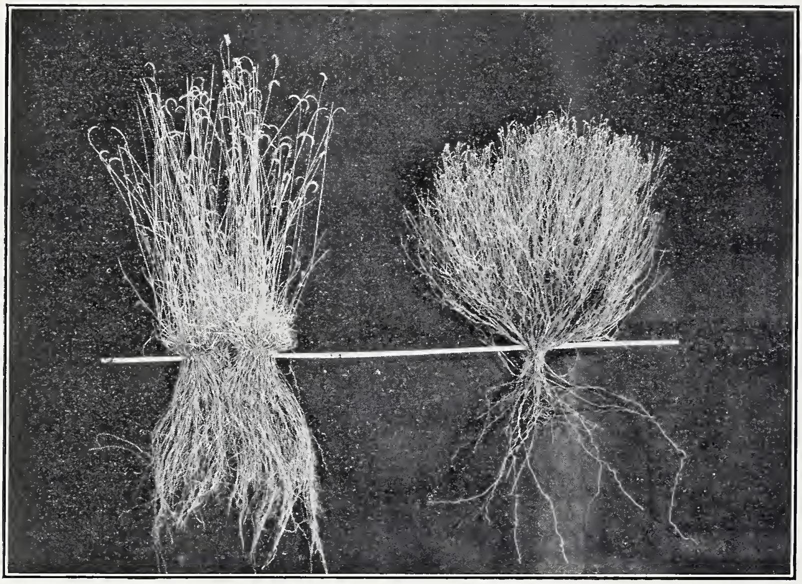


FIGURE 12.—*The aim of erosion-control measures is to restore the vigor and density of erosion-resistant types of vegetation quickly. The palatable blue grama grass (left) is an excellent soil protector. The unpalatable snakeweed (right), a taprooted plant, offers little protection to the soil.*

# Controls and Cures

So far this bulletin has dwelt on the destruction accelerated erosion is causing in the Southwest. The causes of rapid erosion of the surface soil, gullying and arroyo cutting, unprecedented flood damages, silting of river channels, the loss of irrigated lands by waterlogging and riverbank cutting, and the rapid rate at which storage space in reservoirs is being displaced by silt have all been traced to the changes that have occurred in the cover of vegetation following overuse of the range, road building, plowing, and the removal of trees.

The story now turns to controls and cures.

The cure for soil erosion is through restoration of the plant cover. Only vegetation maintains the soil in physical condition to resist erosion. Roots and decaying organic material in the soil help to make it porous, and permit water to filter readily through the topsoil into the subsoil. The organic matter in soil and litter over the surface prevent silt from clogging the tiny underground passageways. The canopy of leaves above the ground intercepts the rain and breaks its disturbing impact on the soil. Stems and plant litter slow run-off, and humus and roots help to bind soil particles together.

The aim of erosion-control measures is to restore the vigor and density of erosion-resistant types of vegetation quickly (fig. 12). This transformation in the range cover in depleted areas cannot be expected to come quickly, even under conservative management. Many years must pass before the full benefits of conservative range management can be attained, particularly in the drier parts of the Southwest. Where soil and plant depreciation are farthest advanced, perhaps 50 years must elapse before the perennial grasses will be restored to anything like their original vigor and density. Some areas may not recover for hundreds of years. When all of the topsoil has been stripped from the land, exposing a hard, impermeable underhorizon, it will be extremely difficult for nature to reestablish grass; and if a salty underhorizon of soil is exposed, nature may require thousands of years. Most of the range fortunately may be expected to recover more quickly, perhaps in 10 or 15 years and possibly less, to the point that erosion will be slowed to less than destructive rates.

Since 1934 the Soil Conservation Service has been experimenting with and demonstrating erosion-control measures in the Southwest. This Service works on private, public, and Indian range and farm lands. In the following pages the erosion-control practices this Service recommends and applies to range and farm



126376°—39——4

land are described. Many of the measures have been thoroughly tried and proved. The Forest Service has dealt with an erosion problem for many years and has uncovered much of the information on which a workable erosion-control program for grasslands as well as for forested lands may be based. Ranchers who have conservatively managed their lands have been freely consulted for guidance, as well as the personnel of the State and Federal experiment stations and agricultural colleges.

Some measures applied to lands in demonstration centers are experimental. In the short period of 4 years some of these have proved helpful in curbing washing and blowing of soil; others have failed or have proved too costly to be practical on lands of low value; and still others have not, as yet, been sufficiently tested.

Whatever measures the Service employs on lands, whether privately or publicly owned, are applied according to terms set down in a written agreement with the owner or administrative agency which controls the use of each piece of land. Under the terms of this agreement the Government, through the Soil Conservation Service, supplies the technical direction required to effect erosion-control measures and practices and directs the work of the C. C. C. boys and Indian or other workmen who help build the fences and other necessary structures. The owner of the land furnishes materials and agrees to abide by a set of management plans which he and a representative of the Soil Conservation Service prepare together.

# Range Management: The Key

The key to control of erosion on range land in the Southwest is range management. The principal factors usually considered under range management are: (1) Proper stocking of the range as to numbers; (2) proper stocking as to kind of livestock; (3) correct seasonal use; and (4) proper distribution of stock over the range.

## Proper Stocking

In proper range utilization, proper stocking as to numbers is most important; without it, efforts toward forage protection and erosion control are usually futile. Until proper stocking is achieved, it is hardly worth while, in the opinion of the technical men of the Soil Conservation Service, to apply additional erosion-control measures. To do so, they feel, is to ignore the teachings of 50 years. The history of the range shows that fundamentally the cause of the present depleted state of plant cover, and excessive erosion, is 50 years of stocking beyond the grazing capacity of the range.

In the Southwest this is considered a highly controversial statement. There are many who will deny its truth, saying that droughts are the cause of range

depletion. "It doesn't rain like it used to," is indeed a familiar complaint, and droughts have, of course, contributed to range depletion. The point of view advanced here is this: Without overstocking, droughts would not have depleted the plant cover to such an extent that changes in plant species, serious losses of topsoil, and widespread and uninterrupted arroyo cutting would have occurred.

There is nothing to indicate that, over a long period, the climate of the Southwest has changed. Studies of tree growth, as revealed by the thickness of annual tree rings, indicate that no important change has occurred for many centuries. Alternating periods of drought and normal weather are recorded by these rings as far back as the records can be read from living trees and from the timbers prehistoric men used in building their homes. Overgrazing by domestic livestock appears to be the only new factor in the situation of sufficient importance to upset natural balances other than temporarily. Before the range was grazed by domestic livestock, the grass survived the droughts and regained vigor and density quickly enough to check soil erosion before it had accelerated to damaging rates.

Many examples of depleted grasslands that have recovered under conservative stocking or exclusion of stock support this opinion. (These examples of recovery have occurred within the last 30 years, which is the period as nearly as meager weather records show, that rainfall has been less than normal.) The watersheds that supply water to Salt Lake City have been mentioned. Many others could be cited, for it is not uncommon to find good grass and little soil movement on one side of a fence and a depleted grass cover and erosion rampant on the other (fig. 13). An unanswerable reply to the complaint, "It doesn't rain like it used to," is, "Five strands of barbed wire won't stop a rain cloud."

On the subject of weather, stockmen are optimistic. They look forward to better weather tomorrow, to better range conditions next year; and they are loathe to reduce their stocking until forced to it by drought and grass famine. Stocking of the range has always been at peak load just as periods of drought began. During each drought, stocking is curtailed, and then in the first seasons of better weather numbers build up, until by the next drought there are more stock on the range than it could support even in good years without detriment to the grass.

As an individual, however, the stockman hardly could have done otherwise than he did if he used public range, at least prior to the passage of the Taylor Grazing Act. If his stock did not graze the range, some one else's would. Without some measure of control over the use of the land, either by ownership, lease, or permit from a public administrative agency, the individual stockman is powerless to adjust livestock numbers to the grazing capacity of his range. Even then he may be pushed by his creditors or by the pressure of high overhead charges to graze more stock than he thinks wise for the good of the range.

The need is pressing for proof that conservative stocking pays in the short run as well as over the long pull. Results of the first 2 or 3 years in the demonstration centers of the Soil Conservation Service seem to indicate that conservative stocking pays almost immediately. Gains in weight of cows and calves, heavier wool clips, larger calf and lamb crops, and smaller death losses strikingly favor conservative stocking when results within a demonstration area are compared with results on overgrazed ranges outside.

The case for conservative stocking is analyzed in Press Bulletin No. 825, Benefits, Based on Nutritional Requirements, from Proper Stocking of Ranges,

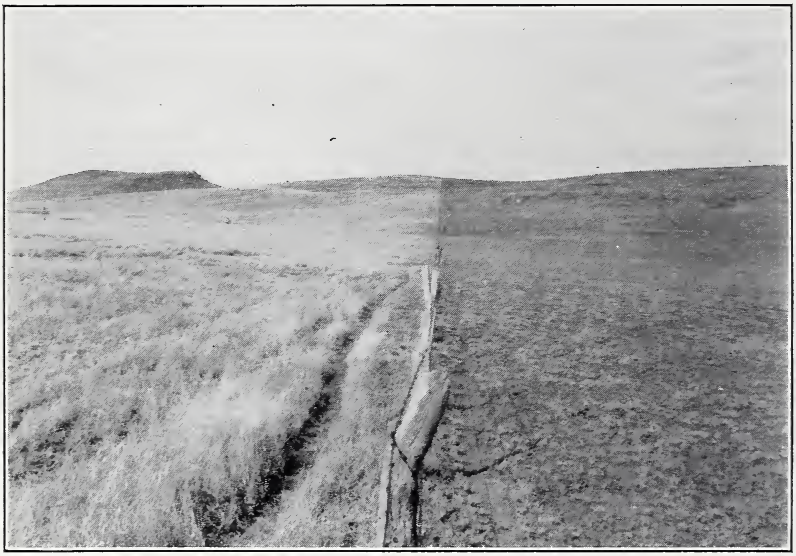


Figure 13.—*It is not uncommon to see a good grass cover on one side of a fence and poor grass cover on the other. The contrast here is due to differences in use and management and not to climate.*

issued by the New Mexico College of Agriculture and Mechanical Arts. The first and most important function of forage, this publication points out, is to maintain the animal. Usually 65 percent of the feed eaten goes for maintenance; that is, to supply heat and energy for digestion, repair of tissues, and locomotion. No other use can be made of the forage until the animal's body needs have been met. Only that which is left over goes toward production. Feed-lot records show that cows getting about a third less feed than those which get enough attain a mature weight of only 750 pounds. This mature weight corresponds closely to that of large numbers of range cattle. Surveys, according to the bulletin, show that cattle having a mature weight of only 750 pounds usually drop a calf crop of about 50 percent, and the calves weigh about 320 pounds at 7 or 8

months. Thousand-pound cows may be expected to produce a 90-percent calf crop, and each may weigh 400 pounds at 7 or 8 months. Figured on an income-per-cow basis, the 750-pound animal produces, on the average, 160 pounds of calf; the 1,000-pound cow, 360 pounds of calf.

It follows then that on overstocked ranges a reduction in stocking plus proper utilization and management will improve the quality of the livestock and result in larger calf and lamb crops and better wool clips, and the plant cover will improve. To assure improvement in vegetation and deceleration of erosion a considerable part of the growth of the perennial plants should be left on the ground to protect the soil during periods of surface run-off and soil blowing.

Before the Soil Conservation Service enters into an agreement to work on a piece of land, it first makes a careful survey of the entire ranch to determine the grazing capacity of each unit. It determines the density of the plant cover, estimates the proportion of perennial grasses, browse plants, and weeds, and, taking into account the palatability of the various species, estimates the number of stock the range can properly support. This estimate is submitted to the owner and, if he agrees to adjust his stocking to the estimated grazing capacity, he and a representative of the Service draw up a range-management plan for the ranch; if not, no agreement is entered into, and the plan is dropped.

The grazing-capacity figure is an estimate, a guide to proper stocking only, and corrections upward or downward are made to hold stocking in line with the condition of the range during usage, always allowing, of course, for a feed reserve. If forage growth and density of cover improve rapidly, the grazing-capacity estimate may be increased; if improvement is slow or if there is drought, stocking is decreased further.

## Correct Seasonal Use

There are wide variations in the amount of forage produced yearly by the vegetation of the Southwest. This variation is a response to climatic factors, principally rainfall. This variation in response may be general or localized. Often within one operating unit the extremes in forage production are as great as they are over large areas.

To establish an adequate plant cover by the restoration of plant vigor and increased density in an area where a fluctuation in forage production exists, a system of use that provides for alternating periods of use and protection is desirable. On range land suited to yearlong use, the deferred-rotation system of grazing provides protection during the seed-producing period on a different portion of the total unit each year. From the standpoint of practical ranch operation there are objections to this system, such as the added cost of fencing or the undesirability of handling stock frequently.

A deferred-rotation system which is flexible enough to permit stocking in line

with the variations in forage production eliminates the major objections to the yearlong grazing system. The objections to yearlong grazing are that it allows continued clipping or cropping of the plants and is inducive to trampling. Both of these results are evident in the patch grazing that goes on under a system of yearlong grazing.

Where range areas are not suited to yearlong use but are seasonal in nature or where ranges that could be used yearlong are used in connection with a national-forest allotment, the rotation system of grazing is advocated. In the latter instance, the rotation plan is so arranged and is flexible enough so that on those areas where the amount of the forage produced is the least, added protection from grazing may be obtained. On range land that is distinctly favorable to seasonal use, control of the opening grazing dates is important. Vegetative readiness is an important factor in the proper use of a seasonal range. Total exclusion for any one or all of the seasonal ranges is advocated as a part of the rotation system only when the range is in such a condition that complete rest is desirable to promote vegetative recovery.

## Aids to Distribution of Livestock

A more nearly uniform distribution of livestock is secured mainly by building fences, by developing water, by herding, riding, and by the proper use and distribution of salt.

These aids help to secure uniform grazing and protect the plant cover by preventing overuse of one part of the range by concentration of stock. Drift and pasture fences enable the rancher to confine grazing use to the proper season and avoid grazing before the range is ready and to practice deferred and rotation grazing. This allows the grass to gain or maintain vigor and produce a

FIGURE 14.—*Whenever possible, watering places are developed not more than 3 or 4 miles apart.*

greater yield of forage as well as seed. Fencing off bull and buck pastures permits a rancher to regulate the breeding season and thus avoid high death losses from lambing and calving in unseasonable weather. Fences also hold down losses from straying and stop trespassing.

Watering places (fig. 14) are developed not more than 3 or 4 miles apart, or closer in broken country, whenever possible, so that stock will not need to travel far for water. An adequate number of watering places holds trailing to a minimum.

FIGURE 15.—*To lengthen the useful life of a stock tank several acres of the watershed immediately above are enclosed, and livestock are excluded. In a year or two the grass becomes sufficiently dense to remove most of the silt load from the water before it reaches the tank.*

Most new watering places are stock tanks. Without some protection, such tanks quickly fill with silt. A novel and successful method of lengthening the useful life of a tank (fig. 15) is to enclose several acres of the watershed immediately above the tank or charco and exclude stock from the enclosure. By putting a gate in the fence the grass within the enclosure may be grazed lightly after seed is matured. The protected area is extended up the sides of the slope so that water does not flow around the fenced area and cut new channels. The recovery of vegetation within the enclosure is rapid, for the vegetation is favored both by location and protection, and in a year or two is sufficiently dense to remove the silt load from the water before it enters the tank or charco. In the milder climates, where there is no danger from freezing, troughs may be installed below the tanks, thus preventing damage to the stock-tank embankment by trampling.

Water is sometimes obtained by improving seeps and springs and piping water from them. Seeps and springs are not uncommonly found in the bottoms of

broad, sandy arroyos. A perforated 8-inch pipe is sunk in the ground 3 or 4 feet deep across the arroyo and below the seep. The perforated pipe fills with water, which is taken out of the arroyo by gravity flow through a 2-inch pipe to a cattle or sheep trough placed above high-water mark.

When no other means of water development offers, a deep well may be drilled.

Salting in little-used areas between established watering places helps to spread cattle over the range. Salting places are changed from time to time to prevent denuding an area and to attract cattle to other parts of the range.

# Structural Aids in Erosion Control

If erosion were controlled in its early stages, when vegetation first starts to give way, when the first small rills are forming in the upper reaches of the watershed, the use of structures would be unnecessary. But over tens of millions of western acres, erosion has gone far beyond the early stages. On many areas where vegetation is depleted, even largely changed in composition and value, and the scant supply of water drains precipitately from it, gullies mark the scene.

The balance has turned so far downwards that structures are needed to tip the balance upward. Since water is the key to a better cover of grass and other vegetation, by holding and spreading water, by stabilizing erosion until vegetation can get a new foothold, structures speed recovery and the control of erosion. Bringing stability during a critical stage, they help to control destructive flash floods that damage property and bring silt loads to stream and river channels.

By increasing water supply and vegetation in depleted areas, structural aids bring a better support to dependent stock and people. They aid plant cover and help rebuild areas where vegetation is so far destroyed and so much soil is lost that conservative use alone will not bring them back.

## Water Spreaders

Water spreaders, as the term implies, are used to spread water that is concentrating in gullies or arroyos. They divert water that is eroding the soil and spread it over higher, gently sloping land. They put water to work growing vegetation—water that would otherwise damage the land by cutting gullies and arroyos deeper and wider (fig. 16). The spreader may be a small or large structure. It may be made of earth, rock, brush, or a combination of these materials.

Hundreds of spreaders may be seen in demonstration centers throughout the Southwest. Most of them are of the smaller type and divert water from the

heads of small gullies and finger arroyos. Many are larger installations, or spreader systems, which distribute water over large areas of meadow or cropland where it once naturally spread from the original shallow channel. The smaller structures, which cost little to build, have unquestionably proved their worth when built of suitable material and placed in properly selected locations. The larger ones, in view of their larger cost and great loss in case of failure, need longer trial before they can be recommended for general use over the range. Time alone can answer some of the questions being raised about water spreading. Will the heavy loads of silt spread over the treated area with the water eventually kill the grass or render the site unsuitable for the present grass species? Meanwhile grass waves over formerly denuded areas, and many millions of tons of soil are being withheld from reservoirs.

FIGURE 16.—*This flat appeared bare of vegetation 2 years before this picture was taken. By spreading water lifted out of an arroyo by a dike, grass was brought back.*

These larger structures spread water from watersheds of several thousand acres. Thus far, after 4 years, most of them are working well. From 62 acres of land below one dike and spreader system at Mexican Springs (fig. 17) on the Navajo Reservation 40 tons of hay were cut in 1936 from land that 2 years before appeared practically bare of grass. This yield is about half that which may be expected from irrigated land. Above another spreader, caring for water from 2,552 acres, 4,600 cubic yards of silt were caught and retained in the arroyo channel. Behind a dike across the Deer Springs wash nearby, 28,760

FIGURE 17.—*One of the dikes and water-spreading systems at Mexican Springs, N. Mex*

cubic yards of silt collected from 3,600 acres. These arroyos, instead of growing deeper and wider with each storm, are healing and revegetating.

Water spreading by means of large structures appears to be an especially promising measure for ranges of low-grazing capacity where most of the feed is grown in small, favored areas. In the lower lands on the upper Gila watershed much of the forage formerly grew on the broad sacaton flats in the major valleys and in the shallow tobosa swales between the "creosote ridges." Although sacaton and tobosa grasses are not highly palatable all the year, they furnish during spring and summer a luxuriant green growth relished by most livestock. And sacaton, even when mature, will be eaten during drought, thus furnishing good roughage to go with concentrates.

In the lower, hard-used portions of the valleys, these grasses, robbed of floodwater from surrounding slopes by quick drainage through arroyos and gullies, have died out. Here, by the use of dikes and water spreaders and by reseeding, it is hoped to restore grass to the flats. The method is illustrated on the Freeman Flat experimental area at Safford, Ariz.

There are 800 acres in Freeman Flat, and 3,000 acres in the headwaters above. An arroyo winds through the flat for several miles, its full length, and at its lower end, at the outskirts of Safford, it poured floodwaters and debris on valuable irrigated lands.

By cooperative agreement with ranchers, control was secured over the whole of the little watershed, and stock were excluded entirely from certain portions.

Some small earth diversion dikes were thrown across the smaller washes. At the upper end of the flat a major structure, a dike, was built across the head of the arroyo. The dike raises the water out of the deep arroyo bed and carries it to each side of the flat. It is then spread in a thin sheet over some 450 acres by a series of rock and wire and brush spreaders. Along with the structural treatment, there was a reseeding and planting program. Perennial grasses—sacaton and Rothrock grama, principally—were seeded on the flat in well-watered locations, and trees and shrubs—willows, tamarisk, and batamote or seepwillow—were planted in the arroyo.

Three years ago, before treatment, the flat was almost completely bare of grass. The sparse vegetation consisted mostly of burroweed, unpalatable saltbush, creosote, and mesquite. After water was spread, some annual grasses and weeds appeared in the first year, then plants of palatable saltbush (chamise) followed by the perennial grasses broadcast behind the spreaders. The stand of grass 2 years after seeding promises in 4 or 5 years to yield possibly 1½ tons to the acre on land on which water has been spread, and pasture for 30 cows for the 4 spring months.

The use of the larger types of water-spreading systems, such as the Freeman Flat example, is limited by soil type and rainfall. If rains are not sufficient or frequent enough, it does not pay to attempt to spread flood flows. Nor does it pay if the soil is without capacity to hold sufficient moisture to start and maintain growth.

Before it was learned that some soils of the Southwest, those which soils men describe as "dispersed," cannot safely be used for making earth dikes, many water spreaders failed. Dispersed soils contain a high proportion of salts, and the soil particles, instead of adhering in aggregates, as most soils do, remain separated in individual particles. There is less body to dispersed soils; in a dike they slough down and shrink, holes appear and enlarge and water rushes through and the dike goes out. If a dike is to be made of earth, the soil material is tested in a laboratory, and if it is found unsuitable, the plan is abandoned.

## Contour Furrows

Contour furrowing (fig. 18) is considered by many to be one of the more effective soil and moisture conservation practices now employed in the Southwest. Contour furrows have proved especially beneficial in areas having a rather high vegetative potential. On soil types of low moisture-holding capacity, on the other hand, contour furrowing appears to have doubtful value, and in dispersed soils the practice also seems to be ineffective; the furrows quickly seal in such soils, preventing infiltration of moisture.

Most contour furrows in the Southwest have been functioning no longer than

2 or 3 years, and it is perhaps still too early to determine definitely their place in an erosion-control program. In the buffalo grass country to the east excellent improvement in contour-furrowed pastures has occurred within 2 or 3 years. In the grama grass and bunchgrass areas of the Southwest the response of vegetation has not been so pronounced, although wherever they have been used the furrows have effectively retarded run-off and erosion. In most places the response in the first year is a good growth of weeds. In the second and third years perennial grasses begin to appear, and it remains to be seen how soon the perennials will displace the weeds.

Throughout the region various types of furrows are on trial on various soil types. The Service is experimenting with spacings and machines for turning furrows. Contour furrows are turned mainly by three types of implements rather generally available: The border and ridging plow used in irrigation farming, the lister, and the walking plow. These three implements make satisfactory furrows 4 to 6 inches deep and not more than 10 inches wide and destroy little vegetation. The disks on the ridging plow are turned, and the soil is thrown to the outside, which makes a double furrow.

Furrowing is limited to slopes lacking adequate vegetative protection where soil washing is evident. No slopes of less than 1 percent or more than 10 percent are being furrowed. Most furrowing thus far is on slopes of 4 to 8 percent.

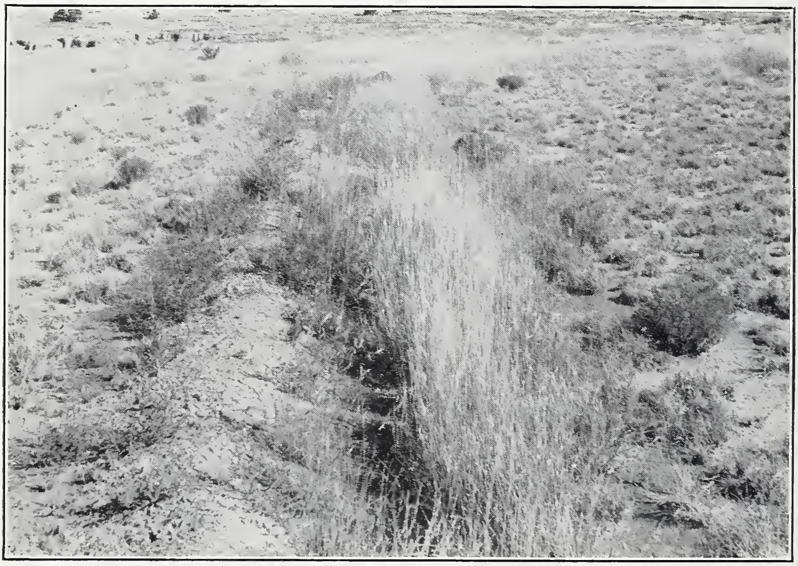


FIGURE 18.—*Contour furrowing is considered one of the more effective soil and water conservation practices now being employed in the Southwest.*

Except in the experimental areas, the furrows usually are spaced 18 to 25 feet apart on such slopes. Spacing on slopes of 1 to 4 percent is 30 to 50 feet, and on the steeper, 8- to 10-percent slopes, 16 to 18 feet.

As a means of controlling run-off, contour furrowing needs no defense. Furrows have in almost all cases retarded run-off and arrested soil erosion effectively. During the first week of March 1938, at St. George, Utah, for example, a furrowed area was severely tested. About 6½ inches of rain fell that week on a denuded area that had been furrowed 6 months before. There was little run-off, whereas untreated surrounding range lands contributed to a severe flood of the Virgin River. Tests following the storm period revealed that moisture had penetrated 27 to 30 inches immediately above and below the furrows and only 15 to 18 inches on untreated areas. Run-off from the untreated areas carried away much of the surface soil and contributed to a flood which ruined many acres of fertile river-bottom lands, drowned livestock, destroyed roads and bridges, and contributed to the silt load carried by the Virgin River toward Boulder Dam. On the furrowed area, there was little soil movement; most of the water entered the soil where it will nourish grass that stock can convert into meat and wool.

## Percolators

Percolators are widely used to retard run-off and silt movement from hillsides. The use of percolators is restricted to land sloping not more than 8 or 10 feet in 100, and to areas of tighter soils which are not amply protected by vegetation but have not, as yet, lost enough soil so that gullies have formed or so that vegetation cannot recover quickly under improved range management. Percolators have proved effective erosion checks under these conditions. Improvement of vegetation along the lines of the percolators, where the soil is caught and held, has been especially noticeable.

Percolators are made of native rock, brush, or a combination of these materials. The spacing is graduated to the degree of slope. The percolators are spaced 30 feet apart on the steeper slopes and 100 feet or more apart on the gentle slopes.

The rock or brush trimmings are laid approximately on the contour. The top of the percolator is level. Usually the percolator extends from one side of the treated area to the other in an unbroken, horizontal line. On areas where there are patches of denser vegetation or pronounced depressions, the percolator lines may be broken. The ends are turned uphill.

The function of the percolator is not to retain water but to retard its flow, and thus allow more time for moisture to penetrate more thoroughly and deeply into the soil. When percolators are made of larger pieces of rock, the rocks are set side by side, touching. When the percolators are made of smaller pieces of rock the rocks are piled loosely in shallow ridges having a base width of about 2 feet.

Brush trimmings are placed with the cut ends pointing downhill. Occasionally the brush is held in place by wire and stakes.

## Crescents

On steeper slopes or rougher areas, crescents may be used in place of contour furrows or percolators, which are not adapted to such lands. These small, crescent-shaped structures of earth are 15 to 18 feet wide from tip to tip and 12 to 18 inches high at the lower side. The points of the crescent are turned uphill. They are used to a limited extent to protect valuable lower-lying lands below from accelerated run-off and deposition of silt or to collect water for tree plantings or other "spot" plantings. From 20 to 25 are constructed on each treated acre.

## Gully Detentions

In the early formative stages of the erosion-control program in the Southwest gully detentions (frequently called gully plugs or check dams) were employed extensively to check erosion on gullied lands. Gully detentions have, on the whole, arrested gully cutting effectively when used on slopes of not more than 15 percent; but they cannot be recommended for general use. The cost is too great for the good they do, except under special circumstances. Gully detentions appear to have a worth-while place when used, for example, to protect irrigated land or irrigation works immediately below a gullied area or to stabilize the bottoms and banks of gullies, or on relatively small watersheds above towns, where they protect from flood damage and conserve muncipal water supply.

Gully detentions cannot be recommended for steeper slopes. Only on the flatter slopes do they catch enough silt to justify their cost.

## Structures to Control Head Cutting

Gully or arroyo-head cuts once started usually continue back through a valley, even when the valley is fairly well covered with grass. Head cutting in this way often destroys the most valuable lands on the range, and control yields large returns, in terms of prevention of damage, in proportion to expenditures (fig. 19).

Quite often it is possible to stop head cutting of large gullies and arroyos by constructing a diversion dike about 50 feet above the cut and spreading the water to either side and below. Sometimes, however, the spreading area is not sufficiently extensive to take care of the water diverted from the gully or arroyo head, or the occasional flow may be greater than the spreader system can care for. In such instances a drop structure made of masonry or concrete or a chute made of these materials may be built in the head cut.

FIGURE 19.—*Head cutting often destroys the most valuable lands on the range. In terms of damage prevented, control yields large returns in proportion to expenditure.*

## Stream-Bottom Fencing

On cattle ranges, use of the range is often concentrated along streams, arroyos, and washes. This is true even where the range is conservatively grazed. Concentration of cattle along drainage channels prevents reproduction of small willows, cottonwoods, and other trees and vegetation which normally stabilize the banks of streams or washes.

The fencing of channel strips a mile or two long and a hundred yards to a quarter of a mile wide is proving successful in controlling erosion along stream bottoms. The natural vegetation is given a chance to take a new hold on the banks of the stream, and protection is provided for artificial plantings or seedings in such areas. A relatively inexpensive process, it often takes the place of structures or provides vegetative protection to structures that may be placed in the channel.

Stock is excluded from these strips after fencing. After 2 years the wider strips may be used as reserve or holding pastures in some cases.

## Range Terraces

Terraces of earth made with teams and scrapers or graders and tractors also are on trial. Range terraces are 18 to 24 inches high and 12 to 15 feet broad at the base. They are level from end to end, and their ends are closed. They are spaced closely enough to catch and retain all run-off from the area between the terraces. At present, percolators or contour furrows are used where several years ago range terraces would have been built. Range terraces are used now only in the rare instances when it is necessary to withhold all water from an area below.

# On the Navajo and Hopi Reservations

The Indian Service and the Soil Conservation Service have joined forces in an effort to bring about better use and management of the resources of the entire Navajo and Hopi Reservations. These agencies and the Indians are developing a working scheme to conserve and perpetuate reservation resources for the continued use of the people. As a first step, 12 demonstration areas, varying in size from 4,000 to 38,000 acres, were selected within the reservation to serve as proving grounds. Work started 4 years ago. The demonstration centers now are fenced, some erosion-control and water-spreading structures have been erected, and new watering places have been developed to permit uniform grazing of the areas. Each demonstration area is stocked to grazing capacity or less, and a herdsman is in charge.

The Ganado demonstration was one of the first to be ready. This 8,000-acre enclosure was stocked to estimated grazing capacity in the fall of 1935. Twelve Navajo sheep raisers furnished 400 ewes. The lamb crop inside the area in the 1935–36 grazing season was 93 percent. Lambs averaged 67½ pounds and brought 7 cents a pound, a premium price. At marketing time, the oldest lambs were only a few weeks over 5 months of age. All were born within a 35-day period. Traders in the vicinity paid a premium because they had contracted to supply buyers with lambs which averaged 55 pounds. The heavier demonstration lambs were in demand to bring up the average weights.

A certain amount of trailing has been eliminated by providing several hundred new watering places and by rehabilitating some of the old. More trailing would be eliminated if the Navajos could be induced to bed their sheep out at night, as range-management men are urging.

Breeding, particularly in the small bands, is usually uncontrolled. Bucks run with the ewes at all times. Most of the lambs are born about the first of April, which is considered at least a month too early. Off-season lambs and lambs of all

ages are common in most bands. Bulls run with the cows the year round, and calves may be born at any time. During severely cold springs the mortality of calves and lambs is therefore unusually high. This problem may be solved by setting aside pastures for bucks and bulls and withholding them from the breeding herd except during certain seasons of the year.

Outside the area, the lamb crop was 61 percent, a third smaller. The average weight of the lambs was 45 pounds, a third less. They brought only 5 and 6 cents a pound. Since the bucks had run with the ewes throughout the year the lambs were of various ages, from 6 to 8 months old, and lacked uniformity.

Inside the area the average wool clip from the ewes was 8.17 pounds; outside the area, 5 pounds, a difference of 3.17 pounds. At 25 cents a pound for wool and 6 cents a pound for lambs, the income per sheep unit inside the area was $5.78; outside the area, $2.90, a difference of $2.88 in favor of the demonstration sheep. The prices received for fleeces and lambs from inside the area were higher than the prices received for fleeces and lambs produced outside the area.

In the grazing season of 1936–37 the record was even better. The lamb crop was 98 percent, 5 percent higher than in the year before, and lambs averaged 73 pounds weaned for market. Traders said lambs outside the area were averaging 55 pounds that season, or 18 pounds less than the demonstration lambs.

The sheep inside and outside the demonstration areas were of the same breed and type. The differences in yield were due to differences in management.

By demonstrations such as these it is hoped to convince the Navajos that conservative stocking and better range management will pay. There is evidence that their interest is becoming aroused. When the first demonstrations were set up it was difficult to induce the Indians to part with their sheep. They did not trust the Government, nor the white man's science, and feared they might lose their stock. This attitude has changed since news of the results at demonstration centers has passed around the reservation. (Four hundred Indians attended field days (fig. 20) at the Ganado demonstration, and witnessed the weighing and selling of the lambs.) More sheep are now offered for demonstration than can be accepted.

While the demonstration areas were being established reservation-wide surveys were begun to determine the condition of the range and the uses to which the land was put; and studies were made of Navajo needs and their range-management and farming practices. Information collected in these surveys was used to devise a reservation-wide erosion-control and range-management program. The reservation subsequently was divided into 18 administrative districts, or range-management units, varying in size from 350,000 to 2,000,000 acres. Management plans were drawn up district by district. Now, in each of these districts the Navajos, by allotment, are gradually bringing about an adjustment of livestock numbers to the grazing capacity of the reservation lands.

FIGURE 20.—*Four hundred Navajos attended field days and witnessed the weighing and selling of lambs raised on the Ganado demonstration area.*

Reduction in numbers of livestock will not come easily to the Navajos, for the Indian stockman, even more than the white stockman, measures wealth in terms of livestock, not dollars. Said E. R. Fryer, general superintendent of the reservation:

> The idea of accumulating wealth in the form of livestock has become so firmly fixed in the mind of the Navajo that he now regards any sale as a reduction. This is true even though such sales may result only in the culling of the herds or the removal of natural increases by normal stock sales. Money, he finds, quickly dissipates, and only sheep and goats provide against the rainy day.

Close culling of livestock would in itself provide some measure of relief to the range, without curtailing the Navajo's income from his band. The attachment of the Indian to his stock is such that he holds on to many more horses than he needs, many aged ewes, barren cows, wethers, and undesirable bulls and bucks long after the stockman with a keener profit-taking sense would have disposed of them. Unfortunately the present grazing capacity of some parts of the range is so low that deeper cuts than mere culling are required to bring livestock numbers down to the point that vegetation may be expected to improve.

Navajo sheep trail the reservation much more than is necessary. The Navajo builds his corral at his hogan (his house) and drives his sheep home each night

and sometimes at noon. He drives them to water, and he drives them to certain browse-plant areas for salts. His band is constantly on the move, often at a trot. By this excessive trailing he harms both his range and his sheep. Navajo sheep, competing for the little grass ahead, seem to run even as they graze. This habit holds over, according to herdsmen, after the sheep are run on a demonstration area where the grass has partly recovered. "They will run for about 2 weeks; then they seem to learn that it isn't necessary. After that they calm down and graze quietly."

## Farming in Navajo Land

The Navajo livelihood by no means depends altogether on stock raising. In fact, about a fourth of the families own no stock of any kind. Farming, rug making (fig. 21), silversmithing, and the collection of pinon nuts make important contributions to the tribal welfare. In the last 3 or 4 years it has been necessary to augment their incomes by programs which provide emergency relief work; and this has helped to carry them through troublesome times. But wage income from soil conservation work, building of roads, fences, stock tanks, and other improvements cannot be relied on as a permanent source of income. Yet, so long as the range continues on the downgrade, the Navajos may be expected to earn less and less from stock. Even though they should adjust their stocking to the grazing capacity of their range, they would probably earn less from livestock

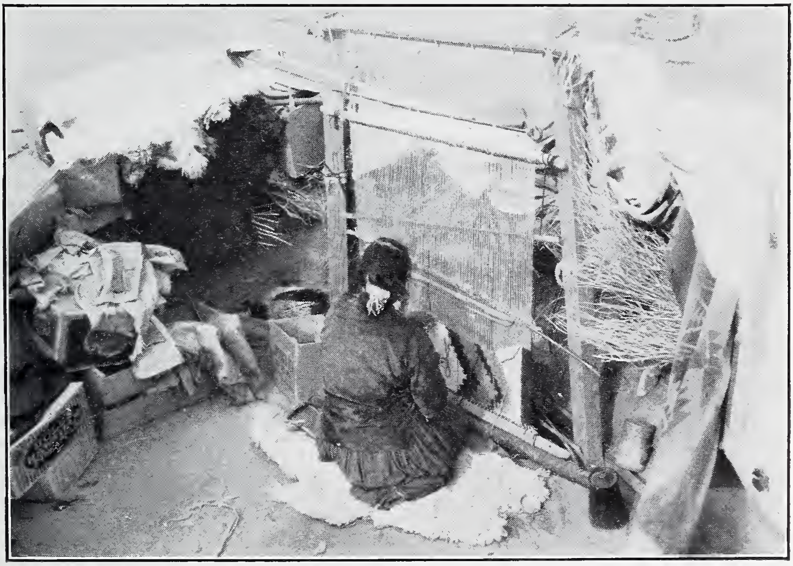


FIGURE 21.—*A Navajo woman weaving a rug.*

than they now do, at least until the range recovered sufficiently to permit heavier stocking, or until the Navajos learned to improve their management practices. This is the Navajo dilemma.

The Navajos spend a large part of their income for food. Perhaps by farming more land, they can produce more of their food at home. Approximately one-fourth of 1 percent of the reservation is now farmed. An agricultural survey in 1935 located 42,300 acres of cultivated crops. Divided among the present population, this is nine-tenths of an acre per person. Farming land, however, is not uniformly distributed. Certain areas, such as the Chin Lee Valley, are highly developed agriculturally, but the typical situation for the reservation as a whole is one of small, scattered fields. The 1935 survey located some 11,000 acres of potential farm land; and more thorough surveys may be expected to increase this figure considerably.

Below most small drainage areas there usually is a small alluvial fan. These fans of alluvial soil are potential fields. They are small, usually not more than 2 or 3 acres, and slope gently. The method of developing these is illustrated on the Navajo experimental area at Mexican Springs. Several of the fans were leveled by the Navajos, working with slip scrapers and teams. Low boundary dikes were built so that fields could be flooded to a depth of about 4 inches. Water was diverted to the fields by spreaders, and rock spillways were provided to carry away excess water. Nine fields containing 6 acres were developed. More beans and corn were produced from these fields than a Navajo family could use. Corn yielded up to 60 bushels an acre; yields averaged 45 bushels an acre. The yields of pinto beans were slightly more than 10 bushels an acre.

Unless it is protected from erosion, much of the Navajo farm land is likely to be lost. Many of the fields lie on alluvial fans, and are irrigated by swiftly moving floodwaters. Often these fields are ruined by severe washing, and abandoned. To preserve them, the Navajo service offers technical assistance to the Indians to enable them to lay out their fields so that damage by washing may be held to a minimum. This may be done on fans of gentle slope by correctly placing border terraces and furrows to spread the water properly and by building dikes and ditches to control flood flow.

The Indians, being ill-equipped to work heavier soils, choose the lighter soils for their farm sites. Light soils blow easily, and wind erosion is severe on many fields. Such soils blow so readily that fields may not safely be cleared of brush until water is available for seeding and growing a cover crop. Otherwise the surface soil may leave the field before the first crop is planted. Fields subject to blowing are protected by planting trees for windbreaks and by strip planting. In the strip-planting plan, crops are alternated so that only a narrow band of soil is exposed to wind action while the intervening band is growing a crop. This method of planting checks blowing sufficiently to preserve the soil until the

windbreak trees are grown. In 1936 approximately 1,300 acres were strip-planted, and the practice proved effective.

# In the Valleys of Northern Utah

Most of the agricultural land in Utah is concentrated in the valleys in the north-central part of the State. These valleys are long and narrow. The rivers flow between ranges of high mountains, fed by small streams that emerge from steep side canyons. Where these side drainages join the main streams, the valleys are widest and the slopes are gentler and more easily reached with irrigation canals. Here much of the irrigated farm land is located.

Many farmers in Utah are stockmen too. They run small bunches of cattle or sheep on the range above their irrigated farms and carry them through the winter in the feed lot on grain and hay grown on irrigated land. Many hold permits to graze their stock on the national forests higher up on the mountain slopes.

The range between the forests above, where grazing is restricted, and the irrigated lands below generally is overgrazed. This land sometimes carries a triple load. It is grazed by stock owned by the farmers in the valley. When the range is part of the public domain, herds and bands of larger outfits may also use it. And many of the valleys are sheep driveways; twice a year several million sheep trail through on their way to and from winter range to the west.

This triple picking of the vegetation depleted it, and accelerated erosion naturally followed. The most spectacular evidences of erosion are the floods and mud-and-rock flows which periodically have come down the side drainages in the last 15 or 20 years, washing out irrigation works and damaging farms, homes, and sometimes whole sections of towns. Gullies, loss of topsoil, and reduced grazing capacity of the range itself, though less spectacular evidences of range overuse, are equally serious consequences.

Just south of Morgan in the Weber River Valley the Soil Conservation Service established a demonstration center in 1936. Except for some dry-farming land on some of the lower slopes, this valley is typical of others in the Wasatch Range north of Price. Very like it are Cache Valley, Ogden Valley, Sanpete Valley, upper Provo River Valley, and numerous other smaller ones.

The demonstration area, 26 miles long east and west and 13 miles wide north and south, comprises 100,000 acres. Here, as elsewhere in the Southwest, the problem of arresting erosion is attacked on a watershed basis. Farmers and stockmen, with the assistance of technically trained men, have begun a control program that starts at the crests of the high, winding ridges and works down the slopes to the irrigated land on the banks of the Weber River, 3 or 4 thousand feet below.

The erosion-control program for range land consists of three steps: (1) Adjust-

ing the numbers of stock to the grazing capacity of the range; (2) instituting a system of seasonal and rotation grazing so that forage plants may bear seed at least once in each 2-year period; and (3) producing enough feed on dry-farm and irrigated lands to carry the stock in the feed lot from October 1 to May 15, approximately, thus enabling the farmer to delay stocking his range until the forage is ready.

From May 15 to June 15 the stock are grazed on spring-fall range just above the irrigated area. After June 15 they are moved onto summer range higher up or, if the farmer holds a permit, into the Wasatch National Forest. They are brought back to spring-fall range after August 15, where they remain until October 1, when they go into the feed lot.

Under a system of rotation grazing the range is divided into several units, and each year grazing is deferred on one of these units until seed is matured and shed. The stock then are turned on to graze and to scatter and trample the seed into the soil so that seed germination is more certain. In the second year another unit is protected until seed is matured, and the cycle of rotation is continued until each unit of the range has enjoyed a protected season, and then the cycle is repeated.

With sheep, proper seasonal use and rotation grazing can be accomplished by herding, but with cattle, fences are required. In the Weber River Valley the farmers and stockmen own about half sheep and half cattle. To put the system into effect with cattle has required building about 120 miles of fence on the 100,000 acres in the demonstration area—drift fences between spring-fall and summer range and fences to separate the range into subunits to permit the practice of rotation grazing. In one locality, where the ownership pattern of the range is particularly complex, 16 men combined their holdings so that such a system might be put into effect with a minimum of new fencing.

Below the range land and above the irrigated land there are several thousand acres of dry-farm land, most of which was cleared for wheat in the World War years. The valley receives 18 or 19 inches of rain a year, and wheat may be grown successfully by summer fallowing in alternate years. Yields are about 25 bushels an acre. Most of the slopes are fairly steep, many rising 15 feet in 100, and they receive a heavy run-off from the grazing lands above when the snow melts in the spring. Gullies have cut through many of the fields, and where they have become numerous, crops no longer can be grown. Light-colored knolls of soil, evidence of advanced sheet wash, have appeared, and gullies are interfering with cultivation across the fields, the long way. Many farmers have had to resort to up-and-down hill tillage,which further increases erosion.

To protect these lands, diversion ditches are constructed across the upper sides of fields to intercept and carry water to natural drainages. These ditches are

built after the manner of a small dike or terrace embankment. Sometimes the range above the fields for a hundred yards or so is contour-furrowed to hold water back.

Once the run-off from the range is diverted, tillage and cropping practices designed to arrest soil movement within the field itself are put into practice. The light-colored knolls, which yield poorly anyway, are taken out of wheat production and seeded to a mixture of grass with alfalfa, or grass with sweetclover. Bromegrass, crested wheatgrass and slender wheatgrass are the species used. Gullies are plowed in and seeded down to the same mixture, and strips of grass and alfalfa are planted crosswise of the field at right angles to the direction of water flow.

These strips, called buffer strips, are about 25 feet wide and are spaced 100 to 200 feet apart on the slope. Spacing is closer when the slope is steeper, and wider when the slope is more gentle, for steeper slopes erode more readily and require more protection. The purpose of the buffer strips is to slow and spread soil and water as they move from fallow or newly seeded wheatland. Thus they serve to minimize sheet washing in the seasons when the wheatland is without the protection of a growing crop.

Stubble is not burned. After wheat harvest the land is listed with a damming lister. As the damming lister moves across a field, it molds the soil into basins about twice the size of a dishpan. The basins collect and hold snow and water until spring, and then they are leveled down, and the field is summer-fallowed. During the fallow season cultivating is done with a duckfoot cultivator, which works in strawy land without trouble. This machine is new to Utah. Cultivation with a duckfoot leaves the soil cloddy. The clods and the straw enable the soil to take up and hold more water than land prepared for fallow with an old-style harrow can. Ordinary fallow cultivation finely pulverizes the soil, preparing it for immediate wash-off during periods of run-off.

The strips planted between the buffer strips of permanent grass and alfalfa are called harvest strips. These are planted in rotation. The rotation includes 1 year of a legume for soil-improving purposes. For example: Wheat, then summer fallow, then wheat, then summer fallow, then sweetclover or alfalfa. The sweetclover is planted in the spring, plowed under in the fall, and followed with spring wheat. Then the field goes back to alternate summer fallow and winter wheat.

## Checkrein on a River

Hugging the banks of the Gila River above San Carlos Reservoir, there are some 50,000 acres of irrigated land. The story has been told of the destruction of 10,000 acres of this land in the Safford area by the twisting, winding, bank-

cutting Gila, one of the muddiest, flashiest streams on earth when in flood. Can this river be tamed and the irrigated land preserved?

Possibly the Gila has always been a muddy stream, but its banks, we know, once were relatively stable and well-defined. When Army engineers surveyed the stream in 1875, the channel was 150 to 200 feet wide. Its banks were lined with cottonwoods and willows. The broad flood plains, now fertile irrigated valleys, were open meadows, with here and there scattered cottonwoods and dense thickets of mesquite. The stream itself did not then flow so violently when in flood, for the grass on the plains and in the valleys and the forests on the higher slopes restrained the flow of water, delivering it more slowly and quietly to the river.

The Soil Conservation Service has undertaken to work with the stockmen and farmers in the whole of the Gila watershed below the boundaries of the national forests in order to place controls on the periodic mad rushes of the Gila. The first step in harnessing the river is to effect adjustments in range management to bring about the recovery of the grass; the next step is to restore vegetation to the banks of the stream; and, finally, to slow the flow of floodwaters across the farm land by tree plantings on certain parts of the flood plain. The program is primarily vegetative in character, which is nature's way, with here and there some mechanical reinforcement to enable nature to work with less interference.

In all, some 50 miles of the river's banks must be protected (fig. 22) at critical places, where the banks are unstable, if further damage is to be prevented. Thus far 7 miles of riverbank have been treated, and plans for 1938 call for treating 25 miles more.

The native black willow is used. Black willow cuttings about the size of fence posts are set 4 or 5 feet apart under the banks. The black willow has a dense, fibrous root system which quickly forms a mat against the bank, and protects the fine-textured alluvial soils beneath from undercutting and sloughing off into the stream. The willows occasionally attain a height of 20 feet in a single growing season and become well-rooted. The first plantings have withstood several floods, but none has been sufficiently violent to test the plantings fully.

In the more vulnerable places the willows are planted behind brush and cable revetments. Mechanical protection is also provided on the outside banks of curves. Usually this consists of cable and log jetties placed across the bow of the channel, or cable and brush anchored at both ends under high-cut banks. Rail tetrahedron lines have been used, and these are effective but expensive.

The materials are supplied by cooperating farmers, and Civilian Conservation Corps furnishes the labor. The willow cuttings, which are obtained locally, cost about $800 a mile. Where mechanical aids are needed, the cost is four or five times greater.

The valley slopes about 15 feet in a mile, and floodwaters therefore flow rapidly.

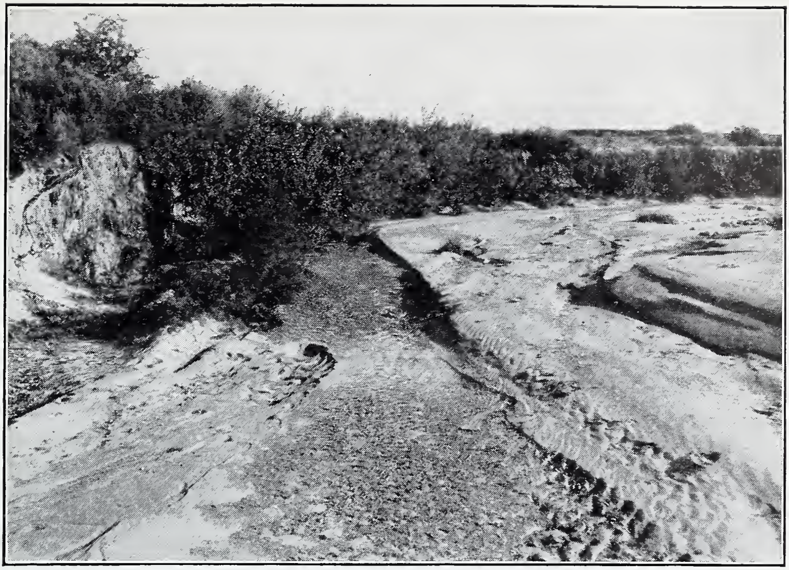


FIGURE 22.—*Year-old willow plantings under the banks of the Gila River at Safford, Ariz.*

The mesquite thickets and cottonwoods on the flood plain once slowed the velocity of flow, and silt carried by the river settled on the valley floor. Without tall-growing vegetation to slow flood flows the floodwaters tend to remove rather than deposit soil. A system of tree plantings, extending from the banks of the river back to the high water mark, is designed to take the place of the thickets and cottonwoods that once checked the velocity of flow. These plantings are spaced 1,000 feet apart.

# On Dry-Farming Lands in New Mexico

One may travel for miles over the upper and middle Rio Grande watershed and notice little dry farming; yet about half a million acres have been broken out for crop production. In certain areas like Mountainair and San Antonito a considerable portion of the land is devoted to crops, principally beans and some forage crops for work stock.

The dry-farming areas are located in the areas of higher altitude where the rainfall is at least 14 inches a year. In such areas conservation of moisture is one of the principal problems. Rainfall is limited and evaporation rates are high. It is essential, in order to grow crops successfully, to hold as much of the precipitation on the land as possible. Measures used to conserve soil also help to conserve moisture. Moisture stored in the ground by such practices as contour

tillage, terracing, strip cropping, and contour listing pushes yields higher. In the bean-producing district around Mountainair, one of the work centers of the Soil Conservation Service, bean yields from 31 fields in which soil and water conservation practices were employed averaged 244 pounds an acre. In 62 fields farmed in the ordinary manner the average yield was 170 pounds an acre.

Some of the farming practices that contribute to soil and water wastage from dry-farming lands are: Continuous growing of soil-depleting and erosion-permitting crops, such as dry beans; failure to cultivate on the contour and thus make use of the water-storage effect of ridges thrown up by tillage implements;

FIGURE 23.—*In the fall all beanfields are listed on the contour to prevent soil blowing and to hold the winter snows.*

failure to grow supplementary feed for livestock; and farming slopes too steep for cultivation.

On farms under agreement much of the cultivated land sloping up to 10 percent is terraced. On the steeper slopes and in the small, irregular-shaped fields small terraces having a base width of 12 to 16 feet are used. These terraces are spaced closely enough to hold a 2-inch rain. They are made level from end to end, and the ends are closed. These smaller terraces are seeded down to a permanent cover, usually a mixture of native grasses and sweetclover. On the more gentle slopes, and especially in the larger fields where larger units of field machinery may be employed economically, larger, wider terraces having a base width of 24 to 30 feet are built. These terraces are cultivated and may be main-

tained by back furrowing to the terrace ridge once a year. These, too, are level, with closed ends.

Contour farming is practiced on all cultivated fields under agreement, whether terraced or not. All rows are made to follow the contour of the land. In the fall all beanfields are listed on the contour. The lister furrows reduce soil blowing in the fall and prevent run-off in the spring, when the snow melts (fig. 23). Farmers are encouraged to use a "double-row tillage system" that leaves permanent ridges in the field during the growing season after the lister furrows have been leveled and the crops planted. An alternative is to practice deep-furrow cultivation, which provides water-conserving furrows during the rainy season.

Crops are grown in strips, or contour bands, so that at least a part of each field is in condition to resist washing and blowing. In the areas devoted principally to growing dry beans the acreage of feed crops is increased. Such crops as sorghum, hegari, the small grains, and Sudan grass are planted in strips. The location of the strips is changed from year to year.

Badly eroding land that is unsuitable for cultivation, such as the steeper slopes and unproductive or droughty soils, is seeded to grass and left in sod permanently. Grass is seeded also in cultivated fields that have been farmed for a number of years and have lost much of their fertility. It is intended that such fields shall remain in grass 5 or 10 years.

# Extending Controls and Cures

It is a peculiarity of the erosion problem that in its early stages, while erosion can be checked easily, the land user is not sufficiently impressed with its seriousness, and usually ignores it. And then later, when damage has become widespread and erosion has become difficult to control, individuals cannot cope with it adequately, and public assistance is required. This has been true of the older farming regions in the East, and it certainly is true in the Southwest.

The nature of the problem, the consequences which follow unrestrained soil washing and blowing, and the character of conservation measures are such that a cooperative attack appears to be the only feasible way of reaching a solution. Until recently the mechanism for making a cooperative attack was lacking. Within the past 2 years, however, a number of States have passed soil conservation districts laws. These laws permit, for the first time, individual ranchers and farmers and State and Federal agencies to pool their resources and deal with soil erosion cooperatively. Colorado, New Mexico, and Utah have State soil conservation districts laws. Such legislation is also under consideration in Arizona.

The basic principle underlying these laws is democratic. The laws of the three States place the responsibility for formulating and carrying out an erosion-control program squarely on the shoulders of local people. They require, moreover, that the initiative for the program must come from local people and arise from local needs. No district can be formed unless the people want it, and then not unless they register this want first by petition and later by a favorable vote in a referendum. Once the district is formed, control of its affairs rests in the hands of local people.

It is not the purpose here to describe the provisions of these laws or the procedures for establishing a district. These are set down in Miscellaneous Publication 193, issued by the Department of Agriculture, entitled "Soil Conservation Districts for Erosion Control." The purpose here is to state that the United States Department of Agriculture welcomes this opportunity to work with ranchers and farmers in the Southwest, through the cooperating groups the State soil conservation districts laws permit land users to organize. The locally selected supervisors of districts undoubtedly will need help in carrying out the kind of soil conservation program that local people want. They will need the benefit of the discoveries of the State agricultural experiment stations,

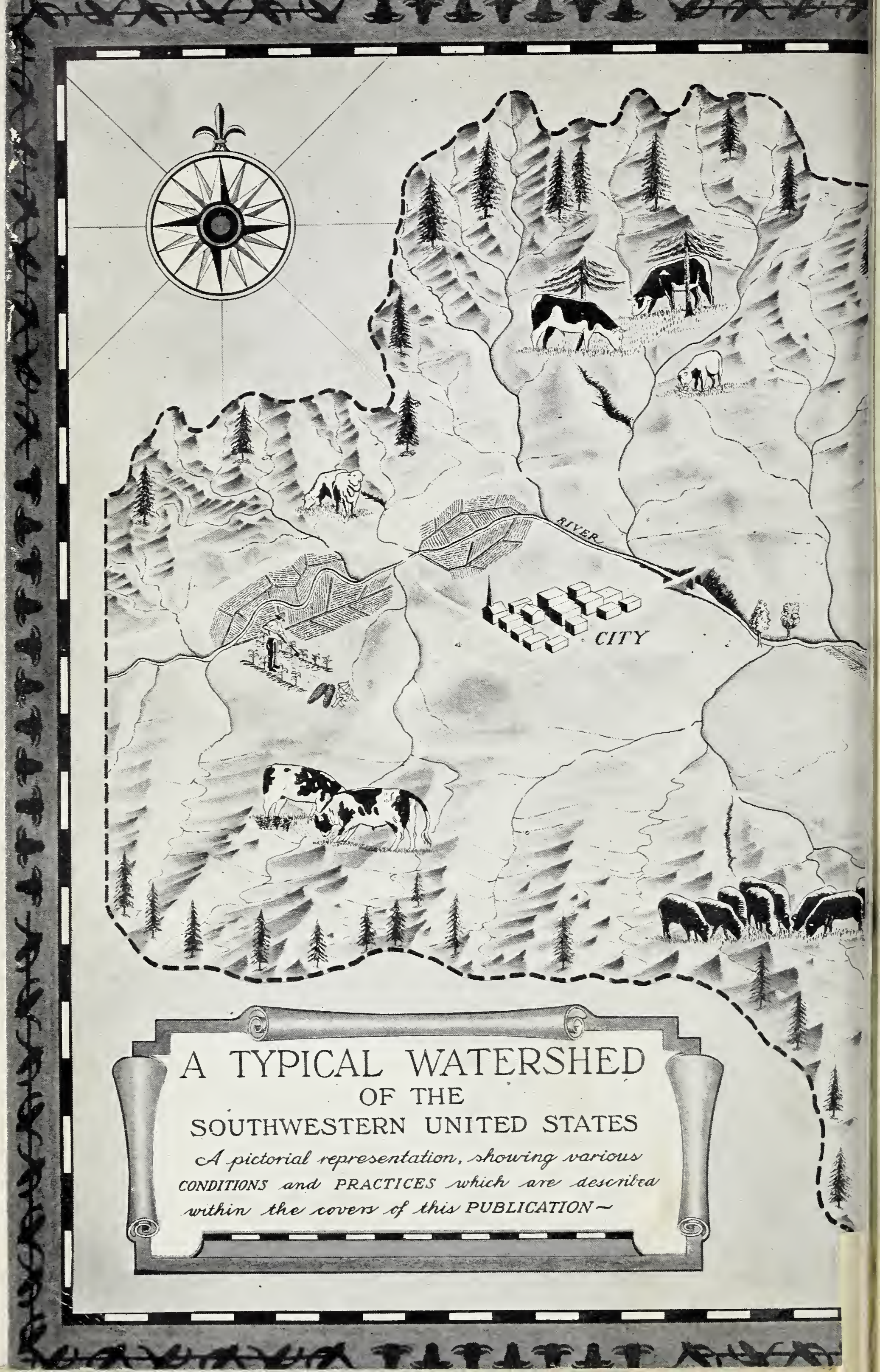
and the help of the educational services of the land-grant colleges. They may need financial help, technical assistance, or seed and plant materials. And they will want, as the laws provide, to turn to whatever public agency is in a position to help them.

The erosion problem in the Southwest, as well as elsewhere in the United States, has become a matter of public concern. Its solution calls for a sharing of responsibility by land users and society. The Department of Agriculture offers its assistance.

## ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

| | |
|---|---|
| *Secretary of Agriculture* | HENRY A. WALLACE. |
| *Under Secretary* | M. L. WILSON. |
| *Assistant Secretary* | HARRY L. BROWN. |
| *Coordinator of Land Use Planning and Director of Information* | M. S. EISENHOWER. |
| *Director of Extension Work* | C. W. WARBURTON. |
| *Director of Finance* | W. A. JUMP. |
| *Director of Personnel* | ROY F. HENDRICKSON. |
| *Director of Research* | JAMES T. JARDINE. |
| *Solicitor* | MASTIN G. WHITE. |
| *Agricultural Adjustment Administration* | H. R. TOLLEY, *Administrator.* |
| *Bureau of Agricultural Economics* | A. G. BLACK, *Chief.* |
| *Bureau of Agricultural Engineering* | S. H. MCCRORY, *Chief.* |
| *Bureau of Animal Industry* | JOHN R. MOHLER, *Chief.* |
| *Bureau of Biological Survey* | IRA N. GABRIELSON, *Chief.* |
| *Bureau of Chemistry and Soils* | HENRY G. KNIGHT, *Chief.* |
| *Commodity Exchange Administration* | J. W. T. DUVEL, *Chief.* |
| *Bureau of Dairy Industry* | O. E. REED, *Chief.* |
| *Bureau of Entomology and Plant Quarantine* | LEE A. STRONG, *Chief.* |
| *Office of Experiment Stations* | JAMES T. JARDINE, *Chief.* |
| *Farm Security Administration* | W. W. ALEXANDER, *Administrator.* |
| *Food and Drug Administration* | WALTER G. CAMPBELL, *Chief.* |
| *Forest Service* | FERDINAND A. SILCOX, *Chief.* |
| *Bureau of Home Economics* | LOUISE STANLEY, *Chief.* |
| *Library* | CLARIBEL R. BARNETT, *Librarian.* |
| *Bureau of Plant Industry* | E. C. AUCHTER, *Chief.* |
| *Bureau of Public Roads* | THOMAS H. MACDONALD, *Chief.* |
| *Soil Conservation Service* | H. H. BENNETT, *Chief.* |
| *Weather Bureau* | F. W. REICHELDERFER, *Chief.* |

O


RIVER
CITY
A TYPICAL WATERSHED
OF THE
SOUTHWESTERN UNITED STATES
A pictorial representation, showing various
CONDITIONS and PRACTICES which are described
within the covers of this PUBLICATION ~